FLORIDA STATE GEOLOGICAL SURVEY

E. H. SELLARDS, STATE GEOLOGIST

FIRST ANNUAL REPORT
1907-08

ADMINISTRATIVE REPORT
MINERAL INDUSTRIES
BIBLIOGRAPHY OF FLORIDA GEOLOGY

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E. H. SELLARDS

CAPITAL PUBLISHING CO., State Printer,
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PHOSPHATE MINING IN FLORIDA BY FLOATING DREDGE, DUNELLON, FLA.

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LETTER OF TRANSMITTAL.

To His Excellency, Hon. N. B. Broward,
Governor of Florida.

Sir:—

I have the honor to submit herewith the First Annual Report of the Florida State Geological Survey covering the operations of the Survey for the year ending June, 1908. The miscellaneous results of this first year's work are included in this report. The special investigations which have been carried on during the year will form the subject of separate publications, one of which, a bulletin on underground water supply, accompanies this report. A report on the general geology and stratigraphy of Florida forming a part of co-operative work between the National and State Surveys is in preparation.

Permit me to express at this time my appreciation of the interest you have shown in the work of the State Geological Survey, and the encouragement you have given in the prosecution of this work.

Respectfully,

E. H. SELLARDS,
State Geologist.

Tallahassee, Florida,
July 1, 1908.

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FIRST ANNUAL REPORT OF THE FLORIDA STATE GEOLOGICAL SURVEY.

By E. H. Sellards, State Geologist.

The State Geological Survey was authorized by the General Assembly of 1907. The act establishing the Survey reads as follows:

AN ACT establishing a Geological Survey for the State of Florida, to provide for the appointment of a State Geologist, to define his duties, and to provide for the maintainance of the survey.

Be it Enacted by the Legislature of the State of Florida:

Section 1. That the Governor of the State shall appoint a suitable person to conduct a geological survey of the State; such person shall be known as the State Geologist, and shall have his office at the Capitol.

Section 2. The State Geologist shall appoint subject to the approval of the Governor such assistance as he may find necessary to enable him to successfully, and with reasonable dispatch, accomplish the object of the survey, and such assistance shall be entirely under the control of the State Geologist.

Section. 3. The State Geologist shall make to the Governor annually a report of the progress of his surveys and explorations of the minerals, water supply and other natural resources of the State, and he shall include in such report full description of such surveys and explorations, occurrence and location of mineral and other deposits of value, surface and subterranean water supply and power and mineral waters, and the best and most economical methods of development, together with analysis of soils, minerals and mineral waters, with maps, charts and drawings of the same; and it shall be the duty of the State Geologist and his assistants, when they discover any mineral deposits, or other substance of value, to notify the owner of the land upon which such deposits occur. Failure of the said Geologist to notify the owner of such deposit before disclosing to any other person or persons, shall subject said Geologist to a fine of one thousand dollars and six months' imprisonment.

Section 4. It shall be the duty of the State Geologist to make collections of specimens illustrating the geological and mineral features of the State; one suit of which shall be deposited in the office of the State Geologist, at Tallahassee, and duplicate suits in

the libraries of each of the State Colleges; each suit to be correctly labeled for convenient use and study.

Section 5. That for the purpose of expeditiously and thoroughly carrying out the provisions of this act, there shall be appropriated out of any moneys in the Treasury not otherwise appropriated the sum of seven thousand five hundred dollars per annum. The Comptroller shall, upon the requisition of the State Geologist, when approved by the Governor, draw his warrant on the Treasurer for the amount so appropriated in such sums as may be needed from time to time for the purpose of said survey as herein set forth; and for all such expenditures made under the provisions of this act, except for the payment of the salary of the State Geologist, as herein provided, the consent and approval of the Governor shall be obtained, and the vouchers for all such expenditures made from this fund shall be filed with the Comptroller; and a statement of his receipts and expenditures shall be printed in such annual report of the State Geologist. Of the amount annually appropriated, there shall be expended: First, for the salary of the State Geologist, two thousand five hundred dollars per annum, which salary is hereby fixed at that sum. Second, for the contingent expenses of the survey, including compensation of all temporary and permanent assistance; traveling expenses of the geological corps; purchase of materials or other necessary expenses for outfit; expenses incurred in providing for the transportation, arrangement and proper exhibition of the geological and other collections made under the provisions of this act; for postage, stationery and printing, and the printing and engraving of maps and sections to illustrate the annual reports, five thousand dollars, or so much thereof as may be necessary.

Section 6. All chemical, analytical or assay work shall be performed by the State Chemist and his assistants, at the direction of the Governor, upon request of the State Geologist.

Section 7. All laws and parts of laws inconsistent herewith are hereby repealed.

Section 8. This act shall take effect upon its passage and approval by the Governor, or upon its becoming a law without such approval.

Approved June 3, 1907.

The Purposes and the Duties of the State Geological Survey.

The State Geological Survey is intended to serve both an economic and an educational purpose. Provision is made for the exploration of the mineral and other natural resources of the State, and for the publication in a suitable manner of the results of such explorations. The establishment of a State Survey upon a basis that is broad, efficient, and capable of development is an accomplishment upon which a State is to be congratulated. The successful carrying out of such a survey demands on the part of its officials faithful, persistent adherence to definite plans, and on the part of the people of the State a generous and constant co-operation. Among the specific objects for which the Survey exists, as stated in the enactment, is that of making known information regarding "minerals, water supply, and other natural resources of the State," including the "occurrence and location of minerals and other deposits of value, surface and subterranean water supply and power, and mineral waters, and the best and most economic methods of development, together with analysis of soils, minerals and mineral waters, with maps, charts, and drawings of the same".

While strictly economic purposes are thus emphasized, a distinctly educational function of the Survey is indicated by Section 4, which makes it the duty of the State Geologist to make collections of specimens illustrating the geological and mineral features of the State. One set of these specimens is to be deposited in the office of the State Geologist, while duplicate sets are made accessible to each of the State colleges. These collections form the basis upon which the conclusions of the Survey's investigations rest and their proper care and preservation is a matter of importance. The educational work of the State Survey should, however, go beyond the distribution of collections. The minute investigation of a mineral deposit and publication of the results of that investigation are

matters of interest not merely to the individuals who may happen to own or mine from these deposits, but are matters which concern the people of the State as a whole. A State Survey will fall short of its responsibilities and opportunities if it does not, through its publications, furnish to the people a better knowledge of the resources of the State and the possibilities and limitations of such resources.

In its economic relations, a State Survey touches on varied phases of the State's development. In its results it may be expected, judging from the experience of similar surveys in other States, to contribute not so much to sensational or sudden development of great mineral deposits as to an intelligent development of the State's natural resources. Its educational value is of no less immediate concern to the State, both to the citizens within the State and to prospective citizens without.

In view of the size of the State and its varied resources, it is apparent that for efficiency the Survey must concentrate its work for the present along specific lines. A thorough investigation of some one natural resource, with the publication of the results, is of much more value to the State than incomplete reports on the many resources. It will be the plan of the State Survey to investigate and report on such natural resources specifically, as, for instance: The underground water supply of the State, artesian and non-artesian, its possibilities for agricultural, commercial and general usage; the phosphate deposits; the fuller's earth deposits; the clays; the road making materials; the sand and cement materials; the fuels; and similarly, other natural resources as they develop. The results of these investigations will constitute a series of economic reports. Other reports, not lacking in economic value, but intended particularly as of educational value, will relate to the general geology of the State. Finally, it is hoped that it may be possible to issue reports of combined educational and economic value treating of the

State by limited areas in detail, as by counties, and intended as final reports for the areas so treated.

MEMBERS OF THE STATE SURVEY FORCE.

The writer's services as State Geologist began in June, 1907. On August 15, 1907, Mr. Herman Gunter was employed as Field Assistant. In connection with co-operative work between the State and the National Surveys, the State Survey secured during a part of the year the services of F. G. Clapp and George C. Matson. The chemical work of the State Survey is provided for by law through the office of the State Chemist.

Mr. Gunter's time has been given largely to field work on underground water, to the collection of geological material, and to assistance in the exhibition of specimens. Messrs. Clapp and Matson, who worked with the State Survey in co-operation with the National Survey, have in preparation a report on the general geology and stratigraphy of the State. This report will contain a geological map of the State, and, if practicable, a topographic map with contour lines at intervals of 50 feet. Mr. E. Peck Greene served as office assistant during the months of March and April. Miss Nellie Mathes has served as stenographer during a part of the year. The total cost to the Survey in salaries for the year as shown by the financial statement given on a later page was $3,568.03.

The State Geologist has given attention in detail, so far as possible, to the field work of the Survey, as well as to the equipment of the office, and to the correspondence. Many of the letters of inquiry received by the office admit of a brief reply, while others require considerable time, and in some cases investigation or examination of specimens, in order to supply the information desired.

Two publications have been issued during the year as follows: A pamphlet on the Organization and Plans of the State Geological Survey, and a circular containing a map with explanatory text showing the areas of artesian

flow in the State. A bulletin on the underground water supply of central Florida accompanies this report.

CO-OPERATION WITH THE NATIONAL GEOLOGICAL SURVEY.

The State Geological Survey has fortunately been able to co-operate during the year with the National Geological Survey. This co-operative work, planned soon after the organization of the State Survey, includes a detailed investigation of the stratigraphy and underground waters of the State, and has been carried on throughout the year in accordance with the original plans. The State Survey has profited very greatly by assistance from the National Survey and by the presence of members of the National Survey in the field. Moreover, the State has had the benefit of a much more extended geological investigation than would otherwise have been possible. The results of these investigations will be embodied in a special bulletin on the stratigraphy and general geology of the State and in reports on the underground water supply.

RELATION OF THE SURVEY TO OTHER ORGANIZATIONS.

Geological Surveys of Neighboring States:—Geological formations are limited by no such lines as State boundaries, and an intelligent study of a formation often necessitates a knowledge of its extent and development in a neighboring State. The relationship of a State Survey is therefore close with neighboring States, and particularly with adjoining States. This relationship in the case of the Florida Survey is especially close with Georgia and Alabama. With more distant States there is a no less real relationship growing out of a similarity of deposits, and of methods of study and development.

Office of State Chemist:—The Survey law provides that analytical work necessary to the investigations of the Survey shall be done by the State Chemist. The Survey is thus brought into co-operative relation with the Division

of Chemistry of the Department of Agriculture and in so far as the work of the Survey contributes to agricultural interests, to the Department of Agriculture as a whole.

The State Agricultural Experiment Station:—In its study of the water supply in relation to agriculture, of soils in their geological relations, and in other ways, the work of the State Survey may be expected to supplement certain lines of work of the State Experiment Station, the two organizations being of mutual aid to each other. The Director of the State Experiment Station has, during the present year, very kindly supplied a considerable number of analyses of water samples which have been incorporated in the bulletin on underground water, prepared to accompany this report.

The Survey Library.

An effort has been made during the year to bring together those publications which are necessary to the immediate and future work of the Survey. The Survey library now contains more than 1,000 volumes. These include the reports of the several State Geological Surveys; the Annual Reports, Bulletins, Monographs, Professional Papers, Water Supply and Irrigation Papers, and other publications of the National Geological Survey; the reports of the Canadian, and a few other foreign Geological Surveys; and many miscellaneous volumes and papers on geological subjects.

Exhibition of Geological Material.

The Survey law provides for the exhibition of geological material. The space available for this purpose is unfortunately as yet very limited. A part of one room has, however, been used for this purpose. Three cases have been built, designed to serve the double purpose of storage and exhibition, the lower part of the case being adapted to the purpose of storing material. In making the collec-

tions a systematic plan has been followed to secure a representation of the rocks, minerals, and fossils of each formation in the State. The collections will be added to as opportunity permits.

THE RELATION OF THE STATE SURVEY TO THE OWNERSHIP OF MINERAL-BEARING LANDS.

The relation of the State Survey to the ownership of mineral-bearing lands is specifically defined. The Survey law provides that it shall be the duty of the State Geologist and his assistants, when they discover any mineral deposits or substance of value, to notify the owners of the land upon which such deposits occur before disclosing their location to any other person or persons. Failure to do so is punishable by fine and imprisonment. It is not intended by the law, however, that the State Geologist's time shall be devoted to examinations and reports upon the value of private mineral lands. Reports of this character are properly the province of commercial geologists, who may be employed by owners of land for that purpose. To accomplish the best results, the work of the Survey must be in accordance with definite plans by which the State's resources are investigated in an orderly manner. Only such examinations of private lands can be made as constitute a part of the regularly planned operations of the Survey.

SAMPLES SENT TO THE SURVEY FOR EXAMINATION.

Samples of rocks, minerals and fossils will be at all times gladly received, and reported upon. Attention to inquiries and general correspondence are a part of the duties of the office, and afford a means through which the Survey may in many ways be useful to the citizens of the State.

The following suggestions are offered for the guidance of those submitting samples:

1. The exact location of all samples should be given. This should be carefully written out in full and placed on the *inside* of the package.
2. The statement accompanying the sample should give the conditions under which the specimen occurs, whether an isolated fragment or part of a larger mass or deposit.
3. Each package should be addressed to the Florida State Geological Survey, Tallahassee. The name and address of the sender should be plainly written on the outside.
4. Transportation charges, whether by mail, express or freight, should in all cases be prepaid.

THE COLLECTION OF STATISTICAL INFORMATION.

For many purposes the collection and publication of statistical information is helpful, both to the industries concerned and to the general public. Such statistical information is desired from all the mineral industries of the State. Such information will be recognized as strictly confidential in so far as it relates to the private business of any individual or company, and will be used only in making up State and County totals. The co-operation of the various industries of the State is invited in order that the best possible showing of the State's products may be made annually.

FINANCIAL STATEMENT.

The following is a summary of the expenditures of the Survey for the year ending June 2, 1908:

Office supplies and equipment	$ 919.34
Field supplies and equipment	402.93
Expense of field operations	2,183.42
Exhibition of geological material	155.93
Express, freight and drayage	24.49
Printing	83.55
Stationery and postage	162.31
Salaries	3,568.03
	$7,500.00

SKETCH OF THE GEOLOGY OF FLORIDA.

A scientific study of the mineral industry is necessarily based upon a knowledge of the geology. The summary of the geological features of the State is given briefly at this time since the subject will be dealt with in more detail in a later bulletin to be issued by the State Survey.

Florida lies within and is a part of the general coastal plains deposits of the United States. These embrace a strip along the Atlantic and the Gulf coasts, varying in width and covering the eastern part of New Jersey, Delaware, Maryland, Virginia, North Carolina, South Carolina, Georgia and all of Florida, as well as much of the southern part of Alabama, Mississippi, Louisiana, and Texas. The formations of the coastal plains are sedimentary, containing much clay, shale, limestone and sandstone, and lie nearly horizontal or with but slight dip. The sediment making up these deposits, except the organic material of the limestone, came from higher lands to the north and west. The sea occupying the present position of Florida, was in early time remote from sources of sediment; so that the proportion of wash from the land was much less here than nearer the original shore line. This clear sea was favorable to the existence of an abundant shell life, their remains accumulating to form lime rock. Hence, in the Coastal Plains section, Florida is exceptional in the large amount of limestone that it contains.

In its general geology, Florida is of comparatively simple structure. The rocks are all of sedimentary origin, no igneous or greatly metamorphosed rocks occurring within the State. The strata lie for the most part, either horizontally, as formed, or with a slightly accentuated dip, and have suffered no great distortion such as often characterizes the rocks of a mountainous country. These sedimentary formations consist of limestones, sandstones, shales and clays. The underlying foundation rock throughout the State, being a massive and very thick limestone.

Formerly it was believed that the greater part, if not

all of the State of Florida, was of coral formation. This view was founded upon the observations of Louis Agassiz and Joseph LeConte. The first publication on the subject by Agassiz appeared in 1852 as an appendix to the report of the Superintendent of the United States Coast Survey for the year ending November, 1851. Agassiz believed that not only the extreme south Florida and the Florida Keys were of coral formation, but that the Peninsula as far at least as the 28th degree of north latitude was of similar origin. LeConte's paper appeared in 1857, and to the conclusions of Agassiz[1] added the theory that the keys rested upon a substructure of inorganic sediment carried by the Gulf Stream. Previous to these publications the true character of the limestone of the mainland had been recognized and described by several observers. J. H. Allen, in 1846, described the limestone outcropping in the vicinity of Tampa.[2] During the same year T. A. Conrad publishes two papers on these formations, giving in the second paper a description of a number of the fossil shells contained in them.[3]. Tuomey in 1851 concurred in Conrad's reference of the Tampa formations to the early Tertiary.[4]

Bailey collected fossil foraminifera during the winter and spring of 1849-50[5] from a locality forty miles west of

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1On the agency of the Gulf Stream in the formation of the Peninsula of Florida. Joseph LeConte, Am. Assoc. Adv. Sci. Proc. X, 103-119, pt. 2, 1857.

2Some facts respecting the Geology of Tampa Bay, Florida. J. H. Allen, Am. Jour. Sci. (2), vol. I, p. 38-42. 1846.

3Observations on the Geology of a Part of East Florida, with a catalog of Recent Shells of the Coast. T. A. Conrad, Am. Jour. Sci. (2), II, 36-48, 1846.

4Notice of the Geology of the Florida Keys and of the Southern Coast of Florida. Tuomey, M. Am. Jour. Sci. (2) vol. XI, 390-394, 1851.

5Microscopical Observations made in South Carolina, Georgia and Florida. Smithsonian Contr. Knowl. II, No. 8, 48 pp. 1851; Am. Jour. Sci. (2), XI, p. 86, 1857.

Palatka and recognized the formation as the "White Orbitulite (Orbitoides) Limestone".

The views of Agassiz and LeConte gained wide circulation and were for a generation the accepted views as to the origin of the peninsula. The credit for again establishing the true character of the limestone of the interior of Florida is due to Professor Eugene A. Smith, State Geologist of Alabama. Professor Smith's paper appeared in 1881, his observations on the geology of Florida having been made during the previous year, while acting as special agent for the cotton culture report of the 10th Census.* While the observations made by Smith were not sufficiently detailed to permit of a differentiation of the several formations occurring in the interior of the State, his conclusions as to the history of the formation of the peninsula were substantially correct.

The Florida deposits are all of comparatively recent date geologically. The place of the formations as now known in the geological time scale is indicated by the table given on the following page.

The Archeozoic at the bottom of the table is the oldest of the large time divisions; the Cenozoic at the top, is the latest. Similarly the Eocene is the oldest division of the Cenozoic, while the Pleistocene is the most modern and leads up through recent formations to the present time.

The oldest formation known in Florida is the Vicksburg Limestone, which is believed to belong, as indicated by the table, to the Oligocene division of the Cenozoic. The conditions under which this limestone was formed were, as indicated by the rock itself, as follows: A clear sea of medium depth free from land sediment in which marine life, especially the minute organisms known as the foraminifera, abounded, the shells of these small animals, along with larger shells, making up the limestone. Of the many fossils occurring in this limestone the most

*Am. Jour. Sci. (3) Vol. XXI, pp. 292-309, 1881.

TABLE OF GEOLOGICAL TIME DIVISIONS, SHOWING FORMATIONS PRESENT IN FLORIDA.

Cenozoic	Recent....	Represented in Florida by....	Sand-dunes, shell-mounds, Indian remains, leading to the present time.
	Pleistocene	Represented in Florida by....	Columbia sands, Marine shellrock, Miami Oolite.
	Pliocene...	Represented in Florida by....	Lafayette formation, Caloosahatchee beds.
	Miocene...	Represented in Florida by....	Chesapeake Miocene.
	Oligocene..	Represented in Florida by....	Upper Oligocene (Chattahoochee and Chipola groups), Lower Oligocene, (Vicksburg and Ocala Limestones.)
	Eocene....	Not known in Florida....	It is probable that the Eocene occurs in Florida underlying the Oligocene at some considerable depth. This inference is based on the occurrence of Eocene limestone to the north and west which dips toward the south beneath Oligocene limestone. It is possible also that Cretaceous rocks occur at still greater depth below the Eocene. There is at present no basis on which to judge the presence or absence of yet older formations beneath the Florida peninsula with the possible exception of the Archeozoic, which is presumably world-wide in its occurrence.
Mesozoic	Cretaceous. Jurassic... Triassic...	Not known in Florida....	
Paleozoic	Permian... Carboniferous Devonian..	Not known in Florida....	
	Silurian... Ordovician. Cambrian..	Not known in Florida....	
Proterozoic	With subdivisions...	Not known in Florida....	
Archeozoic	With subdivisions...	Not known in Florida....	

abundant and characteristic are small foraminifera of the genus *Orbitoides*. From the predominance of these small fossils the formation has come to be known commonly as the Orbitoides Limestone. The formation contains in places large masses of flint. These flint masses seem to have been formed by replacement of calcium carbonate by silica carried in solution by the underground water, which circulates freely through the limestone. Locally, this originally porous and fossiliferous limestone has become compact and more or less perfectly crystallized. Apparently this change is also to be attributed to the effect of underground water. The Vicksburg Limestone doubtless underlies the entire State. It is a part of an extensive formation which encircles the Gulf of Mexico from Florida to Louisiana. In Alabama it makes up apparently the middle part of the St. Stephens or White Limestone, and has there, according to Smith, an estimated thickness of between two and three hundred feet.[1] In Mississippi, Casey recognizes two faunal horizons in the Vicksburg Bluffs[2], the upper of which contains *Orbitoides* as a characteristic fossil. Upon this basis Dall has proposed tentatively for the Orbitoidal phase of this extensive formation the term "Peninsular Limestone", from its typical occurrence in the peninsula of Florida.[3]

In Florida this limemstone lies at the surface in limited areas but is, for the most part, buried beneath later deposits. Good exposures are seen in the central portion of Alachua and in the southern part of Columbia Coun-

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1Report on the Geology of the Coastal Plains of Ala., Geological Survey of Ala. Eugene Allen Smith, State Geologist. 1894, pp. 107-122. The Underground Water Resources of Ala. Eugene Allen Smith, Geological Survey of Ala. 1907. The Ala. Survey has not found it practicable, however, to separate any part of the White Limestone as it occurs in that State from the Eocene. (Coastal Plains, p. 109.)

2Proceedings Academy Natural Science of Philadelphia, pp. 513-518, 1901.

3Trans. Wagner Free Institute Sci. Vol. III, pt. VI, p. 1554, 1903.

ties. It is exposed locally throughout an area extending from Pasco County to South Columbia County and locally west to the Suwannee River. The largest exposed areas lie in Pasco, Hernando, Marion and Levy Counties. Lying upon the Orbitoidal limestone and probably conformable with it is a thin limestone of similar character known as the Ocala Limestone from its typical exposure at the Meffert lime kiln at Ocala. These two formations make up the Lower Oligocene of Florida.

The Upper Oligocene formation consists of limestones and clays. Over much of the north central and western part of the State, these deposits lie at or near the surface, forming a thin coating which rests unconformably upon an eroded surface of the older limestone. The Suwannee River cuts across them between Hamilton, Columbia and Suwannee Counties. They are also cut by the Apalachicola River from Chattahoochee to Bristol. South of the Orbitoidal limestone area these late Oligocene formations crop out along the Hillsboro River, Tampa Bay and elsewhere. They doubtless also extend to the east in that direction underlying later formations.

The Miocene deposits, next above, lie along the east side of the peninsula from Jacksonville to Lake Worth. Deposits representing the same time interval occur in west Florida from Tallahassee to Pensacola, lying between the Oligocene and the coast. Marine Pliocene deposits, consisting of marls and shell beds, occur over much of the southern end of the peninsula, being best exposed along the Caloosahatchee River. Residual and river-formed Pleistocene deposits are to be expected locally throughout the State. A Marine Pleistocene shell rock occurs along North Creek, near Osprey. Similar deposits have been reported from other localities. The Miami Oolite limestone is apparently the most extensive marine Pleistocene deposit in the State. This Oolitic limestone is known to reach north to or beyond Ft. Lauderdale, forming the eastern boundary of the Everglades and dipping to the west. Miami, New River, and other

OCALA LIMESTONE. TYPE EXPOSURE, OCALA, FLORIDA.

streams from the 'glades cut across it. Its present altitude is due to a mild elevation of the east coast which occurred probably during or at the close of Pleistocene time.

The recent formations in the State include rock accumulations of several varieties. Loose sands are not infrequently firmly cemented by the iron deposited from chalybeate springs. A rock so formed, although comparatively recent, may nevertheless be extremely hard. An example of such rock containing numerous snails is found along Sarasota Bay. Marl deposits have been observed to accumulate at the point of meeting of fresh and salt water. Coquina rock forms as a result of the more or less complete cementation of masses of shells. Sand dunes occur along both the east and the west coasts, while shell mounds and Indian remains are found in many places.

Fossils Contained in the Florida Formations.

The fossil record contained in the rocks of Florida is above the average in completeness. This is especially true of the marine invertebrate fauna. From the Oligocene period to the present time there is an almost unbroken series of rock formations made up largely of the remains of such marine invertebrates as lived during the time of the formation of these rocks. W. H. Dall says:* "The State of Florida presents the most complete succession of Tertiary and post-Tertiary fossil-bearing strata of any part of the United States. * * * Nowhere else can the problems of descent with modifications during Cenozoic and later time be so well studied in the fossil and recent faunas." More than fifteen hundred species of invertebrates have been recognized in the Florida formations, and it is probable that a much larger number actually occur. As early as the late Oligocene a few living species of marine invertebrate appear. The proportion of modern species in the fauna increases with each period from that time to the present.

*Bull. U. S. Geol. Survey No. 84, p. 85. 1892.

The record of land life is no less interesting. The earliest land inhabitants of the State yet recorded are the land snails, the shells of which are found sparingly in the Ocala limestone. This was during Lower Oligocene time. The peninsula land area was then, apparently, an island, access to which was for ordinary land vertebrates probably difficult, or even impossible. It is scarcely to be doubted, however, that birds, bats and perhaps many of the small land animals found their way to the islands. An increased elevation occurred following the formation of the Lower Oligocene limestones. Evidence of this upward movement attended by subsequent depression is afforded by an unconformity between the Lower and Upper Oligocene limestones. This movement, if not actually connecting the islands with the mainland, must at least have greatly narrowed the intervening body of water, and may possibly have permitted land vertebrates to reach the peninsula. If so, their remains will doubtless be found imbedded in the Upper Oligocene formations.

By the close of the Chesapeake Miocene the peninsular area was sufficiently elevated to become connected directly with the continent, thus permitting free migration of land vertebrates from the continent. The remains of land animals occur most commonly in clay beds which were doubtless formed along the borders of lakes, streams, and sinks. The land animals found in these clays include the mastodon, the elephant, the rhinoceros, the saber-toothed tiger, horses, deer, bison, tapirs, giant sloths and glyptodons. The fossil remains of these animals are widely scattered, occurring over practically all parts of the State, those which have been described come mostly from the Alachua Clays in the vicinity of Archer and Ocala; from Peace Creek in Manatee County; and from the Pliocene beds of the Caloosahatchee River. They are probably of Pliocene and Pleistocene age. The South American representatives in this fauna came doubtless by the way of the Isthmus of Panama after the connection of North and South America.

RIVER PEBBLE PHOSPHATE MINING, ARCADIA, FLORIDA.

TYPICAL EXPOSURE OF CALOOSAHATCHEE BEDS (PLIOCENE), CALOOSAHATCHEE RIVER, FLORIDA.

A few silicified or lignified tree trunks have been found, and these, together with occasional leaf impressions occurring in the clay strata of the Chattahoochee group give direct evidence of land vegetation in Florida as early as the Upper Oligocene.

FOSSIL HUMAN REMAINS IN FLORIDA.

No State has preserved more definite record of its early human inhabitants than has Florida. The best known human fossils are those which have been obtained from the borders of the Little Sarasota Bay along the Gulf coast of south Florida. The bones found here are changed to limonite. Human remains were reported from this locality by Judge Webb of Osprey, Florida, and sent to the Smithsonian Institution. During 1886 parts of skeletons were obtained by Joseph Wilcox and Angelo Heilprin. Again in 1887, additional remains were collected by Joseph Wilcox. The rock here is a thin stratum of indurated sandstone lying just below the water's edge.

Human remains were also obtained from Rock Island in Lake Monroe. A fossil skeleton was reported from this locality by Pourtalles and Wyman about 1859.* The writer has recently obtained a second skeleton from this locality. The matrix here is a shell rock. There is no evidence that these formations represent other than comparatively recent deposits. The associated fossil shells are of fresh water species representatives of which live along the river at the present time. The skeleton obtained, however, is firmly imbedded in the rock, and while belonging to the recent geological period, is nevertheless historically speaking, very old.

*Wagner Free Ins. Sci. Trans. Vol. II, p. ii, 1889.

PHOSPHATE.

Phosphate mining is Florida's leading mineral industry, the value of this product now exceeding six million dollars annually. Fully twelve million tons with a value of not less than forty-eight million dollars have been taken from the Florida fields from the beginning of active mining in 1888 to the close of 1907.

References to phosphate in Florida began to appear in literature as early at least as 1883. The Proceedings of the National Museum for 1882, published in 1883, contain (p. 47) an analysis of a phosphatic rock found at Hawthorne. The volume on Mineral Resources by the U. S. Geological Survey for the year 1882, published 1883, contains a reference (p. 523) to phosphatic marl occurring in Clay, Alachua, Wakulla, Duval and Gadsden Counties. These references are repeated in Mineral Resources for 1883-84, and in addition, the occurrence of phosphatic rock between Wakulla and the St. Marks River in Wakulla County is recorded. During 1884 and 1885 exploration of the Florida phosphate was made by Dr. Lawrence C. Johnson of the United States Geological Survey. At this time the line of phosphate was traced from Live Oak, in Suwannee County, to Ocala in Marion County. From samples examined and from popular reports phosphate was believed to occur from Thomasville, Georgia, through Hamilton, Suwannee, Alachua, Marion, Sumter, and Polk Counties to Charlotte Harbor in DeSoto County. Most of the phosphates examined by Johnson were of low grade and occur, as he himself recognized, in formations later than the Vicksburg Limestone. The high grade rock phosphate was not discovered by Johnson at this time. Some of the localities mentioned as being examined by Johnson are Preston Sink, 2½ miles north of Waldo; Ft. Harley, 8½ miles northwest of Waldo; the Devil's Mill Hopper near Gainesville; Summers' Quarry, 3 miles west

of Hawthorne; and a locality 3 miles northwest of Newnansville.

Dr. C. A. Simmons of Hawthorne is credited by Johnson as having been the first to recognize and to make use of the Florida phosphate. Dr. Simmons is said to have recognized the phosphatic character of the Hawthorne rocks as early as 1879. A mill for grinding this rock as a fertilizer was operated as early as 1883 or 1884.

Professor Eugene Smith, State Geologist of Alabama, and also Mr. L. C. Johnson, in papers published during 1885, described the Florida phosphates and recognized the localities known up to that time as belonging to formations later than the Vicksburg.

In 1886, Dr. John Kost, State Geologist of Florida, reported phosphate deposits extending through several townships in Wakulla County between Sopchoppy and the Ocklocknee River. Samples from this locality were reported as containing as much as 23.85 per cent of phosphoric acid, (59.05 per cent phosphate of lime).*

Phosphates along Peace River are reported to have been observed by Captain J. Francis LeBaron as early as 1881. Again in 1886 Captain LeBaron made an extended investigation of the Peace River district. His plans for developing the phosphates, however, do not seem to have met with success, and other parties took up the development of this industry. The first shipment of phosphate from the State is reported to have been made in 1888, three thousand tons having been sent during this year to Atlanta.

It was during 1888, also, that rock phosphate in large quantities was discovered in Florida. While putting down a well near Dunnellon in the spring of 1888, Mr. Albertus Vogt observed fossil teeth in a white subsoil. This material proved upon analysis to be a good grade calcium phosphate. This chance discovery resulted in the speedy location of extensive phosphate deposits in this and adjoining sections.

These discoveries were followed by an exceptionally

*Mineral Resources, 1886, p. 617.

active period of development. An excessive number of mining companies were floated, transportation was inadequate, and, on account of exaggerated reports of the quantity of phosphate obtainable, prices were depressed. In spite of these conditions, however, the output, as reported by the National Geological Survey, steadily increased with succeeding years. In 1889, 8,100 tons were produced; in 1890, 46,501 tons; in 1891, 112,482 tons; in 1892, 287,343 tons, and in 1893, 438,804 tons.

The year 1894 is marked by the entrance of Tennessee into the market as a phosphate producer, 19,188 tons having been marketed from that State during that year. During this same year Florida became a leading phosphate producer, having for the first time an output in excess of that of South Carolina. The industry, moreover, was becoming established on a firmer and more rational basis and has continued to grow with succeeding years. The output since and including the year 1904 has exceeded one million tons annually. The amount produced in 1907 was 1,386,578 long tons valued at over six and a half million dollars.*

By way of comparison it may be added that the total output of Florida for twenty years from 1888 to 1907 inclusive, will closely approximate the total output of South Carolina for the forty years, 1868 to 1907. The output in the United States during 1907 was 2,356,486 long tons, more than half of which was produced in Florida. The world's output of phosphate for the year 1905 was something more than 3,500,000 tons. Of this amount Florida produced 1,194,106 tons, or slightly more than one-third. (Min. Resources, 1906.)

Varieties:—Phosphate is an extremely variable mineral. Four leading forms or varieties are commonly recognized in the Florida deposits. They are known as hard rock phosphate, soft phosphate, river pebble phosphate, and land pebble phosphate. No soft phosphate has been produced for a number of years. The relative amount

*U. S. Geol. Survey, Mineral Resources for 1907, 1908.

of the remaining three grades produced, may be inferred from the statistics of 1906. Of hard rock there was produced in Florida in that year 587,598 tons; of land pebbdle phosphate 675,444 tons; of river pebble phosphate 41,463 tons.

Location:—The phosphates of Florida lie principally in a comparatively narrow curved belt reaching from west of the Apalachicola River, southeast and south to the Gulf in Manatee and Lee Counties, a distance of 350 miles.*

The pebble phosphate occurs in the southern part of the area. The principal deposits of rock phosphate occur in the central part of the area in Columbia, Alachua, Marion and Citrus Counties.

Origin and Occurrence:—The origin and occurrence of the Florida phosphates have given rise to extended discussion, and much additional investigation will be required in order to determine doubtful points. First of all, it is not to be assumed that all phosphates originate in the same way. Moreover, phosphates occur in several geological periods and the deposits have been subjected, since their formation, to varying conditions. Phosphoric acid in solution in the water may replace the carbonate of a limestone, forming calcium phosphate. This replacement process is clearly an agent in the formation of rock phosphate. Shells are found occasionally in which the original calcium carbonate has been changed to phosphate, proving the possibility of the formation of the mineral in this way. Phosphoric acid in quantities sufficient to form large deposits of phosphate may have been supplied from any one of several sources.

It is well known that phosphatic material in small quantities occurs widely scattered through various formations. As a result of the progressive decay and wearing away of the surface rock, phosphatic material is concentrated at a lower level, either mechanically, due to the

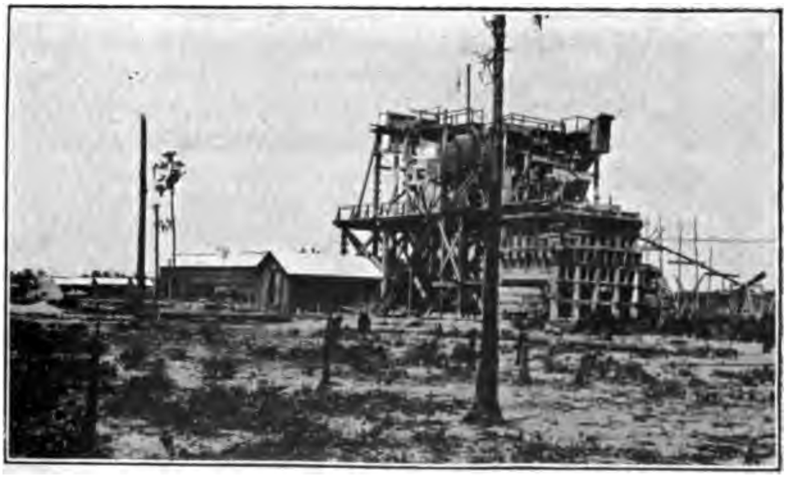
*Eldridge, G. H.; A Preliminary Sketch of the Phosphates of Florida. Trans. Am. Inst. Min. Eng., Vol XXI, 196-231. 1893.

fact that the resisting power of the nodules is greater than that of the surrounding material, or chemically by the replacement process. The hard rock phosphate area has not in the view of several geologists, been continuously exposed since its first appearance above water in Oligocene time. Later formations, originally present, are believed to have been largely removed by erosion. Phosphate, usually of a low grade, occurs in the Upper Oligocene formations in several localities between the Suwannee and the Apalachicola Rivers and in several localities in east central Florida. The Miocene deposits usually contain some phosphatic material, as do also the Pliocene. These later formations, if originally present over the Vicksburg Limestone in the hard rock phosphate section may have served as a source of phosphate which, with the decay of these rocks, accumulated either chemically or mechanically at a lower level. Several other possible sources of phosphoric acid have been suggested. Among these may be mentioned the probability of the addition of phosphoric acid to the limestone from the rookeries of birds.

The land pebble phosphate occurs in the Pliocene formation and represents apparently a stratified deposit of chemical origin.

Future of the Phosphate Industry:—An estimate of the total amount of phosphate in Florida is difficult. The deposits are local and scattered and their extent is to be determined only by extensive prospecting. It is safe to say, however, that the industry, both in the extent of production and in the method of mining, is still in its infancy. Practically all of the high grade phosphate produced is now exported to foreign markets. This condition is unfortunate. Phosphate is one of the earliest of soil constituents to be exhausted, and it is apparently only a matter of time until the American demand will exceed the supply. More regrettable is the waste which accompanies mining. While the phosphate companies operate as economically as present conditions will permit, a large loss in phosphate salts is known to occur.

LAND PEBBLE PHOSPHATE, SHOWING BEDDED DEPOSIT.
BARTOW, FLORIDA.



PHOSPHATE WASHER, BARTOW, FLORIDA.

CLAY.

The term clay is applied to earthy materials which possess in a varying degree the property of plasticity, or stickiness when wet. Clay consists of a mixture of several minerals, rarely if ever of a single mineral. Hydrated aluminum silicate minerals, of which kaolinite is a type, predominate. With these is found quartz, feldspar, mica, iron, and many other minerals. The mineral particles are of varying size and are mixed in widely varying proportions. Chemically, the clays are both complex and variable. This follows as a necessary result of the varying proportion in which the minerals occur. The physical properties differ as widely as do the mineralogical and chemical constituents. Thus in plasticity, clays vary from the remarkable plastic ball clays to slightly plastic kaolins. In texture they may vary from the fine grained clay made up of particles of microscopic size to coarse grained clay grading into sands, sandstones and other rocks. Other properties as tensile strength, porosity, shrinkage, color, and fusibility depend upon the minerals present, the size of the particles, and the conditions in which they occur, all of which give rise to endless variations.

Practical tests of clays must take into account chemical and mineralogical composition, and physical properties. A chemical or ultimate analysis may serve to indicate certain properties of the clays. Thus if the total percentage of fluxing elements is high the clay may be expected to fuse easily. A mineral or rational analysis is intended to determine in so far as possible the minerals present in the clay, and the relative proportion of each. Complete tests of the physical properties require specially adapted devices and machinery.

The clays in Florida are among the promising undeveloped resources of the State. The Survey plans contemplate a thorough investigation of the clays of the State. The sandy clays suitable for road-making material will be investigated in connection with other road-making ma-

terials. The kaolin and fuller's earth deposits will be studied in detail as quickly as this work can be accomplished. Provisions will be made also for tests of brickmaking and other clays, and for the location and extent of clay deposits in the State.

PLASTIC KAOLIN OR BALL CLAY.

The ball clays are among the most important clay products of the State. They are often called kaolins. The term kaolin, however, is best restricted to the white burning, highly refractory, and very plastic residual clays. The Florida ball clays, while they are white burning, and highly refractory are very plastic and are of sedimentary origin. Reis suggests that they be known as plastic kaolins.[1] The ball clays are used largely to mix with the less plastic clays to bring up the grade of plasticity. They contain little or no iron and are of light color. This clay as it occurs in Florida is intimately mixed with coarse sand. There is usually an overburden of a few feet of sand. This is loosened and washed into the pit by force pumps, and is thence removed by suction pumps. The presence of the sand in the clay necessitates washing, after which the clay is allowed to collect in the settling basins. It is then compressed into cakes by which excess of water is removed. The cakes are then broken up and either air-dried or artificially dried for shipment. The deposits at present known lie in the central peninsular section from Putnam to Polk Counties. Putnam County deposits occur in and about Edgar and McMeekin. Deposits have been located in Lake County along the Palatlakaha (Palalakaha) River.[2] Ball clay has also been reported from near Bartow Junction in Polk County, which is apparently the locality farthest south at which these deposits have been found.

[1]Clays, Their Occurrence, Properties and Uses. 1906, p. 165.

[2]17th Ann. Reprt. U. S. Geol. Surv., pt. 3 (cont.) 1895-96, p. 872.

Four plants have been engaged in mining plastic kaolin during 1907. Two of these, under the management of the Edgar Plastic Kaolin Co., are located at Edgar in Putnam County. The two other plants are the Richmond Kaolin Co., of Richmond, Florida, and the Florida Clay Co. of Yalaha, Florida, both in Lake County. The total output of kaolin during the year, as reported by the producers, was 19,615 tons, valued at $97,690.

BRICK MAKING CLAYS.

The surface deposits of north and central Florida contain many clay beds. These clay deposits are often of local extent, and usually of variable character. The sandy clays of the Lafayette and Grand Gulf formations make up the surface deposit over much of the northern tier of counties west of the Suwannee River. Less well defined clays of local extent and variable character occur widely in peninsular Florida. In part these are doubtless the residuum of a former southward extent of the Lafayette; in part of other formations. Many of the clay beds of this area are too sandy for brick material. For this purpose a clay should mold easily, and burn hard at a low temperature without excessive loss from warping and cracking. Such beds as occur in Florida suitable for brick making are confined to no particular geological horizon.

FULLER'S EARTH.

Fuller's earth is a term applied to a variety of clays. These differ from other clays principally in that they are less plastic and possess in a high degree the quality of absorbing greasy substances. This earth was formerly used by fullers to remove greasy spots from cloth, from which usage it received its name of fuller's earth.

Minerals of Fuller's Earth:—The clays, as has been stated, are as a rule complex, both chemically and mineralogically. They consist not of a single mineral, but of a mixture of minerals. Owing to the minute size of the mineral particles, it is usually impossible to identify the

several minerals making up a clay. This is true of fuller's earth as of other clays. Under the microscope the Gadsden County fuller's earth shows angular particles of quartz together with green double refracting particles which Merrill regards as a siliceous mineral.* In fuller's earth from Arkansas, Merrill observed sharply angular colorless mineral particles, faintly double refracting, but lacking crystal outlines or other physical properties such as would determine their exact mineral nature. Angular particles of quartz and a few yellowish iron stained particles suggestive of residual products from decomposition of iron magnesia silicates were also recognized in this sample. The fuller's earth from Surrey, England, according to the same writer, consists of extremely irregular eroded particles of a siliceous mineral and of minute colorless particles suggestive of a soda lime feldspar. Thus it may be said that while fuller's earth is known to consist like most other clays of a mixture of minerals, a satisfactory determination of these minerals has not yet been made.

Chemical Constituents:—There is a wide range in variation in the chemical constituents of different fuller's earths. or fuller's earth from different localities. The range of individual constituents may be inferred from the accompanying analyses.

ANALYSES OF FULLER'S EARTH FROM VARIOUS LOCALITIES.

	I.	II.	III.	IV.	V.	VI.
Silica (SiO_2)	62.83	67.46	58.72	50.36	74.90	63.19
Alumina (Al_2O_3)	10.35	10.08	16.90	33.38	10.25	18.76
Ferric Oxide (Fe_2O_3)	2.45	2.49	4.00	3.31	1.75	7.05
Lime (CaO)	2.43	3.14	4.06	....	1.30	0.78
Magnesia (MgO)	3.12	4.09	2.56	....	2.30	1.68
Potash (K_2O)	0.74	....	2.11	....	1.75	0.21
Soda (Na_2O)	0.20	....				1.50
Water (H_2O)	7.72	5.61	8.10	12.05	5.80	7.57
Moisture	6.41	6.28	2.30	....	1.70	....
Loss on ignition					11.86	....

*Report of the U. S. National Museum 1899, p. 338.

No. I. From Gadsden County, Florida. U. S. Geol. Sur. 17th Ann. Rept., pt. III (cont.), page 880.

No. II. From Decatur County, Georgia. Ibid.

No. III. From Fairburn, S. D. Ibid.

No. IV. Glacialite, Enid, Okla. G. P. Merrill, Non-metallic Minerals. U. S. Nat. Mus., Rept. for 1899, p. 337, 1901.

No V. From Sumter, S. C., U. S. Geol. Surv., Min. Reso., 1901, p. 933, 1902.

No. VI. From Alexander, Ark. Branner, Amer. Inst. Min. Eng. Trans. XXVII, p. 62, 1898.

Physical Properties:—The most distinctive physical property of fuller's earth is that already mentioned, namely, the property of clarifying oils. When wet the fuller's earth is often of a lean character. This, however, is not invariable, as the Gadsden County fuller's earth is sticky when wet.

Test for Fuller's Earth:—Fuller's earth varies in color. It may be light buff, or brownish, or olive green or gray. It is not readily distinguished in general appearance from other clays. When dry fuller's earth adheres firmly to the tongue, but some other clays are also adhesive. A practical test of fuller's earth is necessary in order to determine its value. A test may be made by the use of a glass tube ½ to 1 inch in diameter and 2 to 3 feet long. To make the test support the tube in an erect position, the lower end being plugged with asbestos fiber. The earth is powdered and packed into the tube. Crude oils, vegetable or mineral, are then passed through it. If the clay is a fuller's earth the oils will be more or less perfectly clarified, depending upon the quality of the earth. It has been found that a fuller's earth that will clarify a vegtable oil may not affect a mineral oil, while an earth used to clarify a mineral oil may be unsatisfactory when applied to a vegetable oil. A theory of the action of fuller's earth in clarifying oils is given by Porter as follows: (U. S. Geolo. Sur. Bull. 315, p. 282, 1908): "Fuller's earth has for its base a series

of hydrous aluminum silicates. These silicates differ in chemical composition, but are similar in that they all possess an amorphous colloidal structure. These colloidal silicates possess the power of absorbing and retaining organic coloring matter, thus bleaching oils and fats."

Uses:—The Florida fuller's earth finds its chief use in filtering mineral lubricating oils. According to Day, "The common practice with these mineral oils is to dry the earth carefully, after it has been ground to 60 mesh, and run it into long cylinders, through which the crude black mineral oils are allowed to percolate very slowly. As a result the oil which comes out first is perfectly water-white in color, and markedly thinner than that which follows. The oil is allowed to continue percolating through the fuller's earth until the color reaches a certain maximum shade, when the process is stopped, to be continued with a new portion of earth. The oil is recovered from the spent earth.*" It is also used to some extent for lightening the color of cotton seed oil, and lard oil, although the English fuller's earth is better for these purposes. The original use of fuller's earth, that of cleaning, is now one of the minor uses. It is said to be used in the manufacture of some soaps. It is used in cleaning furs and by druggists as an absorbent, and recently to some extent as a carrier for insecticides.

Occurrence:—Fuller's earth occurs in stratified deposits, which, however, are often of local extent. The geological horizon in which the fuller's earth of western Florida lies has been determined by Vaughan as Upper Oligocene. The geological horizon of the deposit in Manatee County has not been determined.

Location and Extent:—Outcrops of fuller's earth have been reported at many other localities in Gadsden, Leon and Liberty Counties, and Decatur County, Georgia. It is reported to occur as a thin stratum in the Devil's Mill Hopper in Alachua County, and has been identified by the writer on the property of B. S. Quarterman, at Fairfield,

*U. S. Geol. Sur. 21st Ann. Rept. pt. 6, (cont.) p. 592. 1901.

Florida. The wide distribution of fuller's earth in north and central Florida, together with its known occurrence in south Florida, probably indicates numerous deposits not yet located.

Production of Fuller's Earth During 1907:—Three plants were engaged in mining fuller's earth during 1907. These were the Owl Commercial Co.,Quincy; The Southern Fuller's Earth Co., Mt. Pleasant; and the Atlantic Refining Co., of Ellenton, Florida. The total amount of fuller's earth mined in the State during 1907 as reported to the Survey by the producers was 24,148 short tons, valued at $235.443. The product is used principally in the United States, although a certain part of the 1907 product was exported to foreign markets.

PEAT.

Peat has been mined in Florida in an experimental way for several years. Two plants are now being operated during all or a part of the year. The Orlando Water and Light Company has operated a plant near the city of Orlando for several years. The peat at this plant, after removal from the bog, is passed through a kneading machine which disintegrates the fiber and prevents reabsorption of moisture. It is then dried in the open, and after drying is cut into convenient sized pieces for local use as a fuel. Bricketting, which was formerly used, has been abandoned by this company as impracticable for this peat. The Florida Peat Fuel and Construction Company operates a plant near Bayard in St. Johns County.

Such tests of Florida peat as have been made, have been unusually promising. The fuel and gas producing value of peat from the Orlando bog was tested in the fuel and testing plant of the U. S. Geological Survey in 1906. The report on these tests contained in Bulletin 290, p. 134-135 of the United States Geological Survey is as follows:

"In connection with this test of a small quantity of

Massachusetts peat it is deemed advisable to refer briefly to a more elaborate test of peat bricks obtained from Florida, the results of which tests have been obtained in time to be mentioned here, although the test was run subsequent to the date covered by the body of the report. In the producer-gas test of the Florida peat the producer was maintained in operation for fifty hours, and no difficulty whatever was experienced either in maintaining the load or in handling the fuel bed. The peat was furnished by the Orlando Water and Light Company and was secured from a bog near the city of Orlando, Orange County, Florida.

"In starting the producer test the fuel bed was built up entirely of the Florida peat, and the usual preliminary run was conducted before the official test began. The total amount of peat consumed in the producer in the fifty-hour run was 29,250 pounds, or 585 pounds per hour. The average calorific value of the gas produced was 175 British thermal units per cubic foot. During the entire run the average electrical horsepower developed at the switchboard was 205. The amount of peat used per electrical horse power per hour available for outside purposes, including the estimated quantity required for the generation of the steam used in the operation of the producer, was 3.16 pounds, while 2.69 pounds were required per brake horsepower hour at the gas engine, available for outside purposes.

"It should be stated that the peat bricks had been dried and that the moisture content of those used averaged 21 per cent. The gas was particularly rich in hydrogen, running 18.5 per cent, and comparatively low in nitrogen (45.5 per cent).

"As there was a small supply of peat bricks left after the completion of the gas-producer tests, a short run of a little over four hours was made in the boilers. This was not sufficiently long to make any definite conclusions possible, but the results obtained were exceedingly satisfactory so far as they went. No difficulty was encountered in

keeping the boiler up to its rated capacity, and, in fact, during the four hours' run the percentage of rated horsepower of the boiler developed was 113.2. The amount of peat burned per indicated horsepower hour at the steam engine was 5.66 pounds, and per electrical horsepower huor at the switchboard was 6.98 pounds. The calorific value of the peat as used was 10,082 British thermal units per pound. The principal difficulty in the utilization of peat under boilers appears to be the frequency with which it is necessary to fire. On account of the lightness of the material and also on account of its rapid combustion the fireman was kept at work almost constantly during the test." The details of these tests are given in a later Bulletin No. 332, pp. 76-78, 1908.

The great abundance of coal in the United States has delayed the development of the peat industry. Peat deposits are known to be extensive in this country, and with the approach of the exhaustion of coal together with the advance in price as a result of increased cost of mining attention will be directed more and more to peat as a source of fuel. In Florida, in particular, the lack of a local fuel is keenly felt. If present conditions continue the supply of wood will soon be exhausted, while the importation of coal involves heavy freight charges. If the peat bogs can be drawn upon as an addition to the fuel supply the State will be greatly benefited. Some of the European countries, as is well known, have relied upon peat as a local source of fuel for many centuries. Canada, whose coal is less bountiful than that of the United States, has advanced much beyond us in the utilization of peat.

DIATOMACEOUS EARTH.

Diatomaceous or infusorial earth occurs in the State and has been mined to some extent in the vicinity of Eustis. None of this material, however, was produced during 1907.

LIME AND CEMENT.

LIME.

Lime or "quick lime" is chemically an oxide of calcium or calcium and magnesium. It is formed ordinarily by burning limestone, although shells and other calcium carbonates may be used for the same purpose. Limestone when burned gives up carbon dioxide. The residue after burning forming a lime, consists of a calcium oxide, when a pure calcium carbonate limestone is used; or of calcium and magnesium oxide when a dolomitic limestone is used. The reaction in the case of a pure limestone is as follows: $Ca(CO)_3$ when heated breaks up into $CaO+(Co)_2$. In the case of dolomitic limestone a magnesium oxide as well as calcium oxide is formed.

The character of the lime varies according to the amount of magnesium present in the limestone from which it is made. Peppel* offers the following classification of the ordinary or "white limes", including in that term limes containing not more than 5 per cent of sandy and clayey impurities:—

(1) High-calcium, or "hot" or "quick" limes. Made from limestones containing not less than 85 per cent. of carbonate of calcium.

(2) Magnesium limes. Made from limestone containing between sixty-five and eighty-five per cent. carbonate of calcium and between ten and thirty per cent. of carbonate of magnesium.

(3) Dolomitic, or "cool", or "slow" limes. Made from limestones containing more than thirty per cent. of carbonate of magnesium.

These limes differ slightly among themselves. The high calcium or "hot" or "quick" limes set more quickly, while the magnesium and dolomitic limes set more slowly. Limes thus serve different purposes, the high calcium limes being used when a quick-setting lime is desired, while

* Bulletin No. 4, 4th Series, Ohio Geol. Survey, p. 254, 1906.

the other limes are used when slow-setting limes are desired. After calcination, the lime may be placed on the market as quick lime, or it may be slaked and placed on the market as hydrated lime. Hydrated lime is said to be desirable for certain purposes since the lime if properly slaked breaks up into exceedingly fine powder.

The Florida Lime Co., of Ocala, operated three lime plants during 1907. The limestone used is from the formation known as the Ocala Limestone, which is well exposed in and about Ocala. This formation is, however, not restricted to Marion County, but extends as the surface formation south to Sumter County and northwest to Columbia County.

NATURAL CEMENT.

Practically all limestones contain some sandy and clayey impurities. When the amount of clay material present exceeds a certain percentage the product resulting upon burning will set under water and is known as a natural hydraulic cement. Bleininger classes the natural cements as (1) hydraulic limes and (2) Roman cements. The hydraulic limes in this classification are those which contain from 75 to 80 per cent of calcium carbonate and from 20 to 25 per cent of clay. The Roman cements contain 50 to 75 per cent. of calcium carbonate and 50 to 30 per cent. of clay. Peppel, however, proposes to place the range of sandy and clayey matter in hydraulic limes at 5 to 10 per cent, while the range in the natural or Roman cement is given as 10 to 30 per cent. The practical distinction between the hydraulic limes and Roman cements is that the former after burning and upon exposure to the air slake by themselves and evolve considerable heat, while the latter burn to a cinder which must be ground; they also evolve less heat of hydration on slaking than do the limes.

No cements other than lime are at present being manufactured in Florida. Hydraulic cement was formerly

manufactured to a limited extent from a natural cement rock near River Junction. The output from this plant in 1898 is given as 7,500 barrels.*

The formation from which the cement was made is the Chattahoochee Limestone, which is extensively exposed along the Apalachicola and Chattahoochee Rivers above and below River Junction. It is reported that the cement made from the rock at River Junction was of a good quality. It was placed on the market under the trade name of "White Roman Hydraulic Cement of Florida."

PORTLAND CEMENT.

Portland cement is made from raw materials mixed in such manner as to supply the proper constituents for cement manufacture. Ordinarily clay and some form of limestone is used. The clay supplies the silica and alumina, while the limestone supplies calcium or calcium and magnesium. Marl, chalk, or slag, or in fact, any material which supplies the necessary calcium oxide without introducing substances deleterious to the cement may be used if desired instead of limestone. Both the clay or mixture of clays and the limestone must be selected with a view to securing the right proportion of constituents in the resulting mixture. Since both clays and limestone vary greatly in composition each must be selected with a view to supplementing the other. While no Portland cement is being made at present in Florida, both clays and limestone available for this purpose doubtless occur.

SAND-LIME BRICKS.

The materials used in the manufacture of sand-lime bricks are sand and lime. The bonding power of the brick is due to the chemical reaction between these ingredients. The chemical changes occur in the presence of

* 20th Ann. Rept. U. S. Geol. Sur., pt. VI (cont.), p. 547. 1899.

heat, pressure and moisture, and result in the formation of hydro-silicates of calcium and magnesium.

The sand used in the manufacture of sand-lime brick should be comparatively pure and preferably with some variation in the size of the grains. The mixture of lime, sand, and water, is cut out in the form of bricks and conveyed to a hardening cylinder. Necessary heat and pressure is obtained in the hardening cylinder adapted for the purpose. The sand-lime bricks are placed in this cylinder and subjected to a pressure and temperature which varies according to the method of treatment. With a pressure of about two atmospheres and a temperature of 125 degrees C. the duration of exposure in the cylinder should be about seventy-two hours. With a steam pressure of seven to ten atmospheres and 170 to 175 C, six to ten hours' exposure is usually sufficient.

CONCRETE BUILDING BLOCKS, HOLLOW BLOCKS, OR ARTIFICIAL STONE.

The materials for the manufacture of concrete building blocks are sand, gravel, or crushed stone, and cement. The sand intended for use in making cement blocks should be sharp and angular. Coarse grained sand is preferred to fine grained. A mixture of coarse and fine grained sand, however, gives excellent results, and requires less cement, since the relative proportion of voids in the sand is reduced by the presence of the fine grains of sand among the coarse. It has been commonly supposed that a clean sand must be used, but recent experiments seem to indicate that a small proportion of loam or clay is not detrimental. Tests carried on at the Ohio State University appear to indicate that clay or loam up to 15 per cent of the weight of the sand adds strength to a mortar.*

Concrete building blocks have been, as a rule, favorably received throughout the State. The ease of manufacture, together with the relatively small cost of equipment and

*Bulletin No. 2, 4th Series, Ohio Geol. Survey. P. 33, 1904.

the abundance of sand is greatly in favor of this industry. Most cities of considerable size have one or more firms engaged in the manufacture of this material. Sand suitable for the manufacture of concrete building blocks occurs in almost all parts of the State.

MINERALS NEW TO THE STATE.

SULPHUR.

Native sulphur has been found in Florida during the past year, a large mass estimated to weigh two tons having been brought up from the pit of the Dutton Phosphate Company, at Floral City. The phosphate at this place was worked down to the water level as a dry pit and is now being worked below the water level bydredging. The mass of sulphur was brought up on the dipper from about thirty feet below the water level, or a total depth from the original surface of about seventy feet. When first brought up the sulphur mass was mistaken for a rock boulder, which being too large to go through the dipper, was drilled into and blasted. Most of the pieces fell back into the pit, a few thrown on the land were found to be crystallized sulphur with only a slight admixture of impurities. The phosphate beds of Citrus County rest upon Lower Oligocene limestone. The sulphur was found either upon or in Oligocene limestone.

PROBABLE SOURCE OF SULPHUR.

In a Bulletin on the Water Supply which accompanies this report the writer has discussed in some detail the probable source of hydrogen sulphide in underground waters. It is there shown that the hydrogen sulphide in underground water is supplied not from deposits of native sulphur, but from decaying organic matter and from sulphides and sulphates contained in the rock. It is also shown that hydrogen sulphide, while not originating from

FLOWING WELL NEAR PALATKA.

sulphur deposits may itself, under proper conditions, form such deposits. This gas, although not affected by oxygen when dry is, under moist conditions, or in the presence of water containing oxygen in solution slowly oxidized, forming sulphur and water.

In view of these facts, it seems probable that the sulphur mass found at Floral City was formed by the decomposition of hydrogen sulphide gas slowly escaping from the underground waters, the reaction taking place in the presence of a limited supply of oxygen.

While only a small quantity of sulphur has been found in Florida, if the above suggestion as to the origin is correct, the presence of this mineral in workable quantities is not impossible and is indeed even probable.

MINERAL WATERS.

The springs of Florida are famous for their volume of flow as well as for the clearness and beauty of their water and the beautiful scenery about them. Many of these springs are used as health resorts. The United States Geological Survey volume on Mineral Resources reports the sale of mineral waters in Florida for 1907 as 43,430 gallons, valued at $12,378.

The areas in which flowing artesian wells are obtained are indicated on the map which accompanies Bulletin No. 1 of the Florida Survey.

ROAD MAKING MATERIALS.

The rocks of the earth's crust may be classed for convenience of a brief treatment as either igneous or sedimentary. The igneous rocks are those which appear with more or less certainty to have cooled from a molten condition, such as trap, basalt, obsidian, and the granites. The sedimentary rocks are those which are formed by the accumulation of sediments. The sediments may be of purely mechanical origin as in the case of sandstones, shales and clays; or of organic origin as in the case of the limestones. In a broad sense, the sedimentary rocks are made to include even those which are of chemical origin, such as bog iron ore formations. Should one attempt a minute and exhaustive classification of rocks these two main divisions would be found insufficient. Chemical changes are going on incessantly in the earth's crust and affect all rock formations. Chemical and physical forces have in many instances so profoundly altered formations that it is no longer possible to determine whether they were originally igneous or sedimentary. It has been found necessary to establish for these a third division known as metamorphic rocks. With regard to the Florida deposits, however, the classification is not greatly complicated.

The following summary relates to the rock materials occurring within the State, and available for country roads at a slight expense. The more expensive products used in paving city streets are not included.

No igneous formations occur in Florida. All of the rocks of this State are sedimentary. Two classifications are given below. In the first the rocks are classified according to origin; in the second according to chemical composition.

ROCKS OF FLORIDA CLASSIFIED ACCORDING TO ORIGIN.

Rocks of—

Mechanical origin		Sandstones, Shales, Clays.
Organic origin		Shell limestone, Infusorial earth, Muck, peat, lignite.
Chemical origin	Formed by precipitation and chemical segregation.	Bog iron ore, Oolitic limestone, Land pebble phosphate (?)
	Formed by replacement.	Flint or chert, Crystallized limestone, Hard rock phosphate (in part).

ROCKS OF FLORIDA CLASSIFIED ACCORDING TO CHEMICAL COMPOSITION.

Disregarding mode of origin and placing the rocks according to chemical composition, the classification may be arranged as follows:

Siliceous rocks	Flint and chert, Sandstone, Infusorial earth.
Argillaceous rock	Clay, Shale.
Calcareous rock	Shell limestone, Crystallized limestone, Oolitic limestone, Marl.
Carbo-Hydrates	Muck, peat, lignite.
Ferruginous rocks	Bog iron ore.
Phosphatic rocks	Hard rock phosphate, Pebble phosphate.

Siliceous Rocks:—Flint and Chert.

Flint is chemically an oxide of silica SiO_2 with more or less accompanying impurities. It is a variety of the mineral quartz, occurring massive and non-crystallized or more accurately very imperfectly crystallized (crypto-crystaline). The term chert is often used interchangeably with flint. Properly chert is an impure flint or flinty rock. Flint and chert are lacking in cleavage. They break, as do the other varieties of quartz, with conchoidal fracture. A flint rock when crushed breaks into sharp cornered pieces of varying size.

Properties:—The mineral quartz, of which flint is a variety, has a hardness of seven on a scale in which the hardest mineral diamond, is ten. The varieties of quartz vary in hardness slightly according to the impurities that they contain. Silica is one of the least soluble of minerals and among the most resistant to decay.

Occurrence of Flint and Chert in Florida:—Flint and chert occur mostly as masses or "horsebacks" in the limestone formations. A good illustration of the manner of occurrence may be seen in phosphate pits or in some of the pits of the Florida Lime Co., at Ocala. In some of the sinks on Thompson's farm two miles east of Sumterville will be seen flint masses exposed by the natural decay of the limestone. The flint masses appear to conform to no rule as to size and extent. A flint may form a ridge running through the limestone; or again they occur as rounded or elongate masses. Occasionally the flint forms as a thin stratum lying horizontally. This flint bearing limestone lies at no great distance from the surface throughout all of the central peninsular section of the State from Columbia County on the north to Sumter County on the south and from the Suwannee River and the Gulf coast to east Alachua and Marion Counties. Much of the hard rock phosphate rests upon and in this flint-bearing limestone, and from the phosphate pits great quantities of the flint may be obtained. Occasional flint

hills such as that crossed near Evinston and Micanopy stand out as evidence of the resistance of flint to the weathering agencies, the surrounding limestone having disappeared through erosion. This flint-bearing limestone is known as the Vicksburg Limestone. It is not to be inferred, however, that no other Florida formation contains silica. On the contrary, many of the formations are highly siliceous. The Vicksburg Limestone is, however, the chief flint-bearing formation of Florida.

Origin of the Flint in the Vicksburg Limestone:—The flint occurs as has been stated, in masses irregularly distributed through the limestone. Well drillers can bear witness to the frequency of flints and to their distribution through the limestone to a great depth. The flint masses were clearly not present in the limestone as originally formed. This formation when not affected by chemical change consists typically of a mass of calcarous shells of varying size from minute foraminifera to larger bivalves and gastropods with which is interbedded coral and other fossils, along with a limited amount of siliceous material supplied principally by sponge spicules. Originally, without doubt the limestone consisted largely of the remains of these calcarous shells, the flint masses having been subsequently deposited through the agency of underground water. Water in its round of circulation through surface and deeper formations takes silica as well as other substances into solution. In the course of its circulation through the limestone the silica in solution in the water replaces the calcium carbonate of the limestone. The direct evidence that the flint masses are formed by the replacement process is to be had from the examination of a piece of flint. In this it will be seen that the foraminifera and other shells which were originally calcarous have been changed to silica. The replacement process is by no means confined to the formation of flints. As mentioned in the introduction to this chapter, chemical changes are constantly going on among the minerals making up the rock formations, and replacement of one min-

eral by another is one of the important phases of chemical change. This process is again referred to in treating of the limestones.

Calcareous Material.

Calcareous road materials occur in form of shells, shell and coral limestones, oolitic limestone, and marls. All of these rocks consist essentially of calcium carbonate or of the double carbonate of calcium and magnesium, and have certain features in common. They are much less resistant to wear than is quartz. When pure and crystallized the mineral calcite ($CaCO_3$) has a hardness of only three in the scale in which quartz is seven and diamond is ten. It is thus much softer than the steel tires of wagons, and a chief item in the repair of calcareous roads arises from the fact that steel tires cut holes in the soft material. On the other hand, an advantageous property of calcareous material is the readiness with which it re-cements itself. Calcium carbonate dissolves to an appreciable extent in water containing CO_2 gas or weak organic acids. Chemical readjustment is therefore rapid in a mass of ground up or broken calcareous rock, the dissolved calcium carbonate acting as a cementing material.

In practical application, the physical condition in which these materials occur must be taken into consideration. In the case of recent shells the calcium carbonate is in a compact amorphous condition. The shells of a shell limestone are usually more brittle and often crumble easily. The oolitic limestone is made up of innumerable minute round concretions barely large enough to be readily visible to the eye. These are held together by a calcareous cement. After crushing the particles re-cement more or less perfectly. The marls are calcareous deposits containing more or less clayey impurities; they usually fall apart readily. More or less perfectly crystallized limestone occurs locally in the State. Its formation is prob-

ably due to a replacement process similar to that described for flint and chert. The chemical changes in this case involve a rearrangement of the constituent molecules as a result of which the non-crystallized material of the rock assumes a definite form. When partly crystallized the limestone becomes compact and close grained.

Distribution and Amount of Calcareous Rocks:—The calcareous rocks are widely distributed in the State. The Vicksburg Limestone, as already stated, lies at or near the surface over much of central Florida. Oolitic limestones make up an extensive formation running north and south from Miami and forming the east border of the Everglades. Coral and oolitic limestones form the foundation of the keys from Miami to Key West. Shell limestone occurs extensively along the Caloosahatchee River. Tampa Bay affords a compact limestone which often carries much silica. The Chattahoochee series of compact limestones occurs extensively in parts of west Florida. The marls are usually of local occurrence and are restricted to no part of the State Shells, thanks to the oyster industry of the present, and to the shell mound builders of the past, occur in inexhaustible quantities.

ARGILLACEOUS ROCKS—ROAD-MAKING CLAYS.

Fine grained clay mixed in proper proportion with coarse, angular quartz, makes a road that has been found useful where cheapness of construction is necessary, and where the roads have light travel. In mixing sand and clay for road purposes the proportion should be so adjusted that there is just enough clay in the mixture to fill the voids or interstices between the grains of sand. If too little clay is added the sand grains will lack bonding power and will not compact into a solid roadbed. If too much clay is added, the sand grains are widely separated and the road behaves much as though the sand were not present at all. The amount of clay necessary to mix with a given volume of any particular sand may be

roughly determined by ascertaining the amount of water necessary to fill the interstices of the sand. A simple procedure recommended in Farmer's Bulletin No. 311, U. S. Department of Agriculture, p. 10, is as follows: "Two ordinary glass tumblers of the same size are filled to the brim, one with dry sand to be tested and the other with water. The water is then poured carefully from the one glass into the sand in the other until it reaches the point of overflowing. The volume of water removed from the glass which was originally full of water can be taken as an approximate measure of the voids in the unit volume of sand contained in the tumbler. A simple calculation will reduce this to percentage volume."

Since all clay contains more or less sand, it may be expected that certain localities will supply clay that contains the right admixture of sand and clay to form a natural sand-clay road, or so nearly the proper admixture that it will serve that purpose satisfactorily. Fortunately for Florida, almost every county is supplied with an abundance of clay which serves admirably the purpose of road-making. The widespread occurrence of sandy clays in the north, west and central Florida has already been mentioned. The clay in many of these deposits contains sand and clay so proportioned as to make excellent roads. With this material at hand road construction in country sections is carried on at a minimum expense, and the resulting roads, while not all that could be desired, are a great improvement over the ordinary sand roads. They find their greatest usefulness in country sections where cheapness in road-making is necessary. Their special usefulness arises from the fact that owing to their widespread occurrence they can often be obtained from pits near at hand, thus lessening the expense of transportation. Many of these clays have the disadvantage of being sticky after rains. In the open country, however, where these roads find their greatest usefulness a part only of the road is clayed, the remainder of the road remaining sandy is traveled during seasons of rain, at which time

the sand is compact and hard. Thus the sand roads and the clayed roads supplement each other.

The road-making clays are of a red or yellowish color, indicating a high percentage of iron compounds which probably assist in the bonding power of the material. In texture the clay is rather coarse, and breaks up readily.

Bog Iron Ore.

Bog iron ore occurs in various parts of the State, but usually in thin deposits and of local extent. It has been stated by Shaler, (U. S. Geological Survey, 15th Ann. Rept., p. 272, 1895), that where the surface of a limestone road can be covered with iron ore, the firmness of the mass is much increased. An iron oxide, such as bog iron ore, serves as a cementing material, and this is doubtless the explanation of its usefulness for this purpose.

Phosphatic Rock.

Phosphate of a too low grade or too high in objectionable impurities to work commercially may serve in some localities as a useful road rock. The hard rock phosphate is harder than limestone and is reported to have better cementing qualities.

GEOLOGICAL INVESTIGATIONS IN FLORIDA PREVIOUS TO THE ORGANIZATION OF THE PRESENT GEOLOGICAL SURVEY.

The record of the geological investigations in Florida as contained in the literature, is briefly summarized in the following pages. It has been found impossible to mention all of the important papers, and only those which are especially necessary to an understanding of the course of development of the geological researches in this State are included. In the bibliography at the end of the chapter will be listed all the titles that have been found relating to the geology of Florida. This summary is given in the beginning of the State Survey's work in order to take stock, as it were, of the results already arrived at in this field. The numbers given in parenthesis in the text refer to the bibliography.

A number of references to Florida Geology occur in publications issued previous to the acquisition of the territory of Florida by the United States in 1821. M. Catesby as early as 1771, wrote on the natural history of Carolina, Florida and the Bahama Islands (24), and in 1791, William Bartram published the first edition of his travels through North and South Carolina, Georgia and east and west Florida (15). Bartram's account is of interest as being one of the early publications based upon direct observations. William McClure's memoir, "Observation on the Geology of the United States," includes mention of Florida along with the other coastal plains States. The first edition of this work appeared in 1809 in the Transaction of the American Philosophical Society (141). A second edition revised and enlarged was published in book form in 1817, and in the "Transactions" for 1818. The science of Geology at this early date was very imperfectly developed as may be inferred from the fact that McClure accepts the Wernerian classification. Florida was believed to belong entirely to the formation known

as the Alluvium, the fourth division in the Wernerian system.

A paper by John Finch entitled "Geological Essay on the Tertiary Formations in America," published in the American Journal of Science for November, 1823 (69), is credited by Professor William B. Clarke (25) as the first attempt to correlate the deposits of the coastal plains on scientific grounds. This paper refutes the prevalent idea that the coastal plains consist entirely of alluvium. With regard to this point, Finch states, page 32, that:—

"In America, an immense tract of country, extending from Long Island to the sea of Mexico, and from thirty to two hundred miles in width, is called an alluvial formation, by most of the geologists who have written upon the subject, and by some it appears to be considered as an exception to the géneral arrangement and position of strata, which are found to occur in other countries.

"From an examination of fossils brought from that quarter of the United States, from a personal inspection of some of the strata, and the perusal of most of the publications which bear a reference to it, I wish to suggest that what is termed the alluvial formation, in the geological maps of Messrs. Maclure and Cleaveland, is identical and contemporaneous with the newer secondary, and tertiary formations of France, England, Spain, Germany, Italy, Hungary, Poland, Iceland, Egypt and Hindoostan'

Specimens of Florida clays from Escambia Bay, seven miles above Pensacola, contained in the Academy of Natural Science of Philadelphia are mentioned, (p. 37.)

A paper published the following year, 1824, by R. Dietz, contains a description of the coquina rock of Anastasia Island at St. Augustine (63). In a note appended to this paper Thomas Say identifies and lists the shells contained in a mass of the coquina rock.

The territory of Florida, "A recent and valuable acquisition to the United States", is described by James Pierce in a paper published in 1825 (158). This paper, like Bartram's, is based upon actual explorations. Central Florida was visited by Pierce and the topographic features accu-

rately described, including the limestone rock, sinks, natural wells, subterranean streams, "savannas" or "prairies," lakes and hammock lands. A great savanna, believed to be one hundred miles in circumference, located in south Florida (presumably the Everglades), is reported (p. 124) as having been seen by Colonel Gadsden. The existence of a large permanent lake located by maps in the southern part of the peninsula (evidently referring to Lake Okeechobee) is doubted.

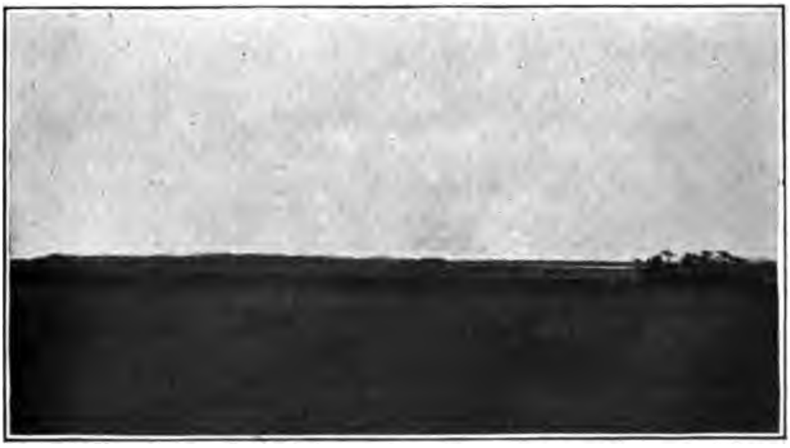
A paper by Charles Upham Shepard, published in 1833 (182) is of interest chiefly from the quotations which are incorporated from Bartram and others, describing the springs of Florida. In referring to Manatee Spring and to a sink described by Bartram as "near Tallahassee," this writer evidently confuses the present city of Tallahassee with the ancient Indian village of Tallahasochte, which was located on the Suwannee River.

A paper published in 1838 by Henry Whiting (205) contains an interesting description of Florida, including some observations of geologic interest. The coraline formations of the keys is noted, the shell formation of the upper St. Johns River is mentioned, and the coquina rock at St. Augustine described. It is interesting to note that at this date both the Everglades and Lake Okeechobee are referred to in doubtful terms.

The next group of papers of importance appeared in 1846. One of these, by John H. Allen (11), entitled "Some Facts Respecting the Geology of Tampa Bay," gives an accurate description of the limestone along the Hillsboro River, together with a partial list of fossil shells contained in the limestone. Allen falls into the error of regarding the limestone at Tampa Bay as identical with the limestone of the interior, including that observed by him in central Florida, and that reported to occur in the Everglades.

T. A. Conrad accompanied an expedition sent out by the Navy Department during the winter of 1842 under the command of Capt. Powell. The expedition visited the

LAKE OKEECHOBEE, ENTRANCE TO THREE-MILE CANAL.



THE EVERGLADES, FROM THE SOUTH TO THE NORTH DRAINAGE CANAL.

St. Johns River and subsequently made its way around the coast past Key West to Tampa Bay. The steamer having entered the St. Johns River, Conrad was able to examine the banks near the early village of Hasard. The banks which are here elevated some feet above the water level, were identified by him as a Post-Pliocene formation. The limestone of the Florida Keys was examined and likewise identified as Post-Pliocene. These observations, with others along Tampa Bay, form the basis of the conclusion that a considerable elevation of the whole of the Florida peninsula occurred in Post-Pliocene time, "a movement which clearly has raised all the Florida keys above water" (28). Arriving at Tampa Bay, the objective point of the expedition, many of the islands and the coast generally as well as the banks of the Hillsboro River to the falls were examined. The formations were regarded as belonging probably to a member of the Upper Eocene period. The second paper by Conrad (29) contains descriptions of a number of species from the "Upper Eocene limestone of Tampa Bay." Conrad had not personally examined the limestone of the interior and like Allen, fell into the error of supposing that the limestone examined at Tampa Bay was the same as the limestone underlying the interior of the State. These papers by Conrad are of interest as being the first to refer the Florida formations to definite geologic horizons. The entire chain of keys are referred to the Post-Pliocene, while the limestone along Hillsboro Bay are regarded as Eocene.

The report of Buckingham Smith on the Everglades of Florida, addressed to the Secretary of the Treasury in 1848, contains observations on the geology (185). The presence of shells belonging to recent species was observed in the Miami oolitic limestone and the Post-Pliocene age of the formation recognized.

Two papers of note dealing with the geology of Florida appeared in 1851. One of these by J. W. Bailey, published in the Smithsonian Contribution to Knowledge, (13) describes fossil polythalamia (foraminifera) from the lime-

stone forty miles west of Palatka, and an infusorial stratum near Tampa. Bailey's description of the silicified foraminifera is of interest as being an early record of the true character of the white Orbitulite limestone of central Florida. Subsequent observations seem to indicate that the supposed infusorial stratum is less distinctly infusorial than was believed by Bailey. (Dall, 45, p. 115).

The second paper of this year is by Tuomey, entitled "Notice of the Geology of the Florida Keys and of the Southern Coast of Florida". (196), Tuomey visited the Florida Keys during the summer of 1850 and recorded his observations the following year in the American Journal of Science. The oolitic structure of the limestone at Key West is noted. The large masses of corals that often occur in the limestone of the Keys were observed and reported by him in this paper. With regard to the elevation of the Keys which has been previously postulated by Conrad, Tuomey, says (pp. 392-393):

> "There can be no doubt that this great chain of Keys diverging from Key Biscayne extending over a distance of one hundred and fifty miles, and having an average breadth of fifteen miles, is due to the elevation of vast uneven coral reef whose prominent points rising above the water, form the foundation of the Keys the sands driven up by the waves having done the rest."

Tuomey agrees with Conrad in referring the limestone at Tampa to a tertiary formation older than the Miocene. Tuomey examined the limestone at the mouth of the Miami River and at the falls of the Miami leading into the Everglades, and describes it as being of the same age as that at Key West, the shells, as previously pointed out by B. Smith, being identical with the shells living in the surrounding water. Tuomey regards the Everglades as resting upon a vast basin of the Miami Limestone. Tuomey distinguishes clearly between this limestone and the Tertiary limestone occurring at Tampa Bay. The mainland along the east coast like the Keys have, in the opinion of Tuomey, been elevated. He says, (p. 394):

"The contour of the ridge surrounding the 'Everglades,' taken together with the structure of the rock of which it is composed, and imbedded organic remains, leads very strongly to the conclusion that it once occupied a position similar to that now occupied by the Keys. And it is evident that an elevation of the Keys of about ten or twenty feet would produce a similar ridge, shutting out the sea from the space, at present, between the reef and the mainland, and producing a second 'Everglade,' differing from the present only in its greater comparative length."

A paper by Agassiz on the "Florida Reefs, Keys and Coast" appeared in 1852, (6). The Florida Keys were examined and described by him in considerable detail. Agassiz expresses the view that the growth of the keys above the surface of the water is due solely to materials accumulated as a result of the action of the wind and waves. He states (p. 153):

"That part of the Keys which rises above the level of the water is, therefore, a sub-aerial and not a submarine accumulation of floating matter, thrown above high-water mark by the tempestuous action of the water. We insist upon the fact, that the Keys furnish in themselves, by the internal structure of their rock, the fullest evidence that they have been formed above high-water mark by the action of gales and hurricanes, instead of having grown as a reef up to the water level, and been subseqently raised to their present height. The evidence of this statement rests upon certain facts obtained from observation of the reef itself, at Sand Key and the Sambos."

On this point Agassiz's views are thus in opposition to the previously expressed views of Conrad and Tuomey. After having examined the Keys, Professor Agassiz examined the rocks along the mainland. These he found to be of the same structure as the rocks of the Keys. He states on page 156 that:

"Along all that part of the shore which was examined, as well as upon the shores of the Miami, we found everywhere the same coarse, oolitic rock, with cross-stratification, consisting of thin beds, dipping at various angles in different directions, *precisely* as we find it at the western extremity of Key

West, excepting, perhaps, that the cross-stratification is here more prominent, the strata dipping more frequently in several directions within the same extent."

Notwithstanding the considerable elevation which the rocks along the mainland attain in the vicinity of Miami, Agassiz was of the view that these rocks, like the rocks of the Keys, had been built above water level by the action of winds and tides. He says on page 156:

"We are satisfied that as far as coral formations have been observed upon the main-land of Florida and within the present extent of the coral reefs, no change of the relative level has taken place either by subsidence or upheavel of the coral ground, and that all the modifications which the reef has presented at successive periods have been the natural consequence of the growth of reef-building corals, with the subsequent accumulation of their products, in the manner described above."

The conclusions of Agassiz with regard to the gradual growth of the peninsula through the agency of corals have given rise to much discussion. On page 157 of this publication he says:

"There we have a peninsula—a narrow, flat strip of land, projecting for about five degrees from the mainland, between the Atlantic ocean and the Gulf of Mexico, and forming an effective barrier between the waters of the two seas, which otherwise, even by the change of a few feet in the relative level of the intervening peninsula, would communicate freely with one another; and this peninsula we now know to have been added to the continent, step by step, in a southerly direction.

"We know that the time can not be far behind us when the present reef, with its few keys, did not exist, and when the channel, therefore, was broader, and the Gulf Stream flowed directly along the main range of keys. We know further, that at some earlier period the keys themselves were not yet formed, and that then the channel between Cuba and Florida was wider still, washing freely over the grounds now known as the mud flats, between the keys and the mainland, and that there was then nothing to impede a free communication between the Gulf of Mexico and the Atlantic ocean. The channel of the Gulf Stream was not only wider—it was also less shallow along its northern borders, for the whole extent of

soundings south of the mainland of Florida was an uncovered coral ground, upon which the deep-water species were just beginning to spread. But we may trace the change farther. There was a time when neither the southern bluffs of the continent, nor Long Key within the Everglades, nor even the Everglades themselves, existed; when, therefore, the Gulf Stream had a broad communication with the Atlantic and the southern shores of the United States extended in almost unbroken contiguity from west to east, from the shores of Texas and Louisiana to St. Augustine. At that time the Gulf channel was, in reality, a broad bay, as broad as the Gulf itself, destitute of all those obstructions which now cause the tropical current to follow such a circuitous course between the West India islands, through the Caribbean Seas, and around the peninsula of Florida. The influence which the Gulf Stream has upon the climate of the Atlantic is so well known, that its connexion with the changes which the current itself has undergone within a comparatively recent period cannot be overlooked."

* * * * * * * * * *

"We have seen how successfully several reefs have been formed, more or less parallel, within the limits of the peninsula of Florida, as well as beyond the mainland. We have seen, also, how these parallel or concentric reefs have been gradually transformed into mainland by the accumulation of coral sand and mud with other loose materials, and also that the keys are now slowly annexed to the mainland by the same process."

A series of rock samples obtained by Agassiz in the course of his investigations of the keys were examined by Horsford and reported upon in two papers, the first of which was published in the Proceedings of the American Association for the Advancement of Science, and with some changes in the American Journal of Science (100). The second paper (101), was called out by criticism of the first by Professor Dana, and is occupied with a defense of his earlier paper. The chief conclusions of these papers are:

"1. That the submerged or oolitic rock has been solidified by the infiltration of finely powdered (not dissolved) carbonate of lime, increasing the points of contact; and the intro-

duction of a small quantity of animal mucilaginous matter, serving the same purpose as the carbonate of lime, that of increasing the cohesive attraction.

"2. That the surface or crust rock has been solidified by having, in addition to the above agencies, the aid of a series of chemical decompositions and recompositions, resulting in the formation of a cement."

With regard to the source of lime in corals Horsford concludes that:

"The carbonate of lime of corals may be due to the decomposition of the sulphate present in sea-water with the exhaling carbonate of ammonia from coral animals yielding insoluble carbonate of lime on the one hand, and soluble sulphate of ammonia on the other."

The General Assembly of Florida passed an act in 1853 establishing the office of State Engineer and Geologist. The geological part of the work, however, seems not to have been provided for. The first report of the State Engineer and Geologist occupies pages 19-36 of Documents accompanying the Message of the Governor of Florida, submitted November 28, 1854. That part of the report relating to geology occurs on page 20 of the appendix and reads as follows:

"On the subject of the Geology of the State, I have made no report, from the fact that the General Assembly failed to specify any duties or make any appropriations to defray any expenses incurred in reference to the matter. Consequently nothing has been done by me, except to obtain specimens of soils and minerals from the various localities (where marked changes were perceptible), visited by me in the performance of the duties of Engineer."

The office of State Engineer and Geologist was abolished by an act of the Legislative Assembly of 1855.

A paper by Professor John LeConte published in 1861 is of interest in its geological relation, from the fact that the writer describes the character of the Florida limestone accurately, stating that it consists typically of a mass of shells, with occasional masses of flint. (117). The

writer had probably not seen the papers by Agassiz and Joseph LeConte, since he makes no reference to them, although his conclusion that the limestone about Silver Springs is probably of the Eocene period is not in accord with the views of these two earlier writers.

Professor Joseph LeConte accompanied Agassiz during the winter of 1851 in his explorations of the Florida Keys, and published a paper in 1857 supporting and developing the views of Pofessor Agassiz (118). He agrees with Agassiz that the growth of the peninsula has been due to successive reefs, and that the elevation of the keys above water is due to wind and tide and not to elevation. LeConte is of the view, however, that the coral agencies are not alone sufficient to account for the growth of the peninsula, since as is well known corals do not grow at a greater depth than ten to twenty fathoms. To account for the successive reefs concentrically disposed from the north to the south, he invokes the agency of the Gulf Stream. LeConte's theory was that the Gulf Stream carried sediment which formed the foundation of the keys. This view necessitates the assumption that the Gulf Stream has shifted farther and farther to the south with the growth of the peninsula until it has come to occupy its present position.

Hunt contributes to a knowledge of the keys in a paper published in 1862, republished in 1863 (103). This writer during a residence of five seasons at Key West, 1857-1862, during which time he was in charge of the construction of Ft. Taylor, was able to observe closely the structure of the keys. Hunt calls attention to the extent of the line of keys to the south and southwest. Hunt agrees with Agassiz in the view that there has been no recent elevation of the keys, but objects to LeConte's theory that sediment carried by the Gulf Stream forms the substructure. This substructure, he believes, to be formed of organic material resulting from shells and corals distributed by a return eddy from the Gulf Stream. The ex-

istence of this return eddy accounts also for the gradual extension of the keys to the west.

In 1865 T. A. Conrad identified three species of invertebrates from the Ocala Limestone. These were found to be Eocene species of California, Maryland and New Jersey. Conrad refers the Ocala rock to the period of the Shark River marl of New Jersey. This paper, (31), like the one by Professor John LeConte, is of interest as identifying the limestone of Florida as Eocene, notwithstanding the papers of earlier date by Agassiz and Joseph LeConte, both of which writers regarded the deposits of the State as of comparatively recent date.

A paper published in 1881, by Professor Eugene A. Smith (186) is of great importance as being the first paper to correct the erroneous views regarding the coral formation of Florida. The underlying limestone of the interior of Florida was identified by him as the Vicksburg Limestone, and was traced by actual outcroppings from Jackson County in west Florida, through middle Florida to Marion County, in south-central Florida. From his own observations and from observations of others, Smith was brought to the conclusion (p. 298):

> "That almost the whole of the State of Florida, from the Perdido River of the west, eastward and southward, including the middle and western parts of the peninsula certainly as far south as the latitude of Tampa Bay, and probably as far as the latitude of Charlotte Harbor, has for its underlying formation the White or Orbitoides limestone of Vicksburg age."

It is now known that the supposed southward extent of the Vicksburg, based principally on the observations of others, was much too great. The essential facts remain, however, that Smith correctly identified the Vicksburg limestone as the foundation rock of the interior of central Florida. Smith records in this paper for the first time the presence of Miocene deposits in Florida, an exposure having been examined by him at Rock Springs in Orange County.

Rock specimens collected by Wilcox enabled Professor Angelo Heilprin to determine in 1882 definitely the existence of a nummilitic limestone in Florida. The specimens examined were taken from the neighborhood of the Chesehouiska River about four miles from the coast. The nummulites were associated in the specimens examined with recent land and fresh water shells. The presence of the genus *Orbitoides,* however, leads to the conclusion that the formation represents the European nummulitic either Eocene or Oligocene (80.)

Professor Alexander Agassiz' bulletin on Tortugas and the Florida Reefs appeared in 1883 (1). Agassiz' investigations led him to the conclusion previously stated by Hunt that the Florida keys had been elongated westward due to the return eddy-current of the Gulf Stream. This return eddy-current was found to carry an abundance of food supply for corals.

Professor Joseph LeConte in 1883, following the appearance of Agassiz' bulletin, recognizes that the sediment forming the foundation of the Florida keys could not have been deposited by the Gulf Stream. On this point he accepts the conclusion of Hunt and A. Agassiz that the sediment is of organic origin. In view of the investigation of Smith on the Geology of Florida. LeConte conceded also that the process of addition of land to Florida by the combined agencies of the Gulf Stream and corals could not have commenced north of the north shore of the Everglades (119.).

Two papers relating to Florida were published by Heilprin in 1884. In the first of these (81), this writer gives further reasons for regarding the Florida limestone as of Vicksburg age and for accepting Conrad's reference of the Vicksburg limestone to the Oligocene. In a summary of the geology of Florida in this paper, Heilprin repeats his observations of the occurrence of nummulitic rock along the west coast, and reviews the additions to a knowledge of the geology of the State contributed by Professor Smith. This paper contains a map (in colors)

of the Tertiary formations of the Atlantic and Gulf States. The map of Florida is based upon Professor Smith's earlier map. The Vicksburg is mapped as reaching to Lake Okeechobee and the borders of the Everglades, the error of regarding the Tampa Limestone as identical with the Vicksburg not having yet been corrected. In the second paper of this year (82), Heilprin describes some new foraminifera from the nummulitic formation of Florida.

Papers by Smith (188) and by Johnson (104), in 1885, record a much greater extent of Miocene deposits over the peninsula of Florida than has been previously supposed.

In 1887 Heilprin's exploration of the west coast of Florida and the Okeechobee Wilderness appeared (92). This publication contains a narrative of a journey along the west coast of Florida from Cedar Keys to the Caloosahatchee River, and thence to Lake Okeechobee, made by Mr. Heilprin, in company with Mr. Joseph Wilcox, in the winter of 1885-'86. A statement of the geological results of this expedition was contained in an advance publication which appeared in 1886 (91). Heilprin points out the fact that with regard to the supposed coral origin, the evidence is very strong, that the structure of the peninsula even beyond Lake Okeechobee is of organic and inorganic material accumulated in the normal way. He also calls attention to the uninterrupted section from the Oligocene to the present, the gradual change in the invertebrate life and to the evidence of the gradual elevation of the peninsula.

Dr. J. Kost published in 1887 a "First Report of the Geological Survey of Florida". This paper derives an added interest from the fact that it was prepared under the authority of the State. Dr. Kost was appointed State Geologist of Florida by Governor Perry in 1886, with the expectation that a continuance of the Geological Survey would be provided for by the Legislative Assembly of the following year. This expectation, however, was not realized. Dr. Kost's report contains observations on the

geology, physical geography, soils and timber, with remarks on the phosphates, lime, marls, clays, iron, coal, building stone, and mineral waters. (114.)

In a paper published in 1888, Mr. Lawrence C. Johnson (105) gives a sketch representing a generalized section across the peninsula of Florida through St. Augustine and Gainesville. This sketch is designed to illustrate the structure of the peninsula. It shows the anticlinal structure of the Vicksburg Limestone, which has a mild dip to the west with comparatively thin surface deposits, and a much more rapid dip to the east with a much thicker Miocene and later deposits.

In 1889, D. W. Langdon, Jr., published the results of his observations along the Chattahoochee River made two years earlier. Mr. Langdon's paper (115) includes a section of Alum Bluff, Florida, and also a section at Ocheesee, Florida. Langdon suggests the name of Chattahoochee group, which he regards as the oldest member of the Miocene or the newest member of the Eocene white limestone.

The publications on Florida Geology for 1890 and succeeding years become so numerous and diversified in character that a review of even important papers is difficult. A number of these have already been mentioned in connection with the phosphate industry of Florida. Some others are listed under fuller's earth. In the following account only the more important publications of a general nature are reviewed. For a more complete list the reader may consult the bibliography of Florida geology which follows this chapter.

In connection with the correlation papers of the Eocene formations of the United States by Dall and Harris (45), the senior author, W. H. Dall, takes occasion to give a summary of the geology of Florida as understood at that time. The stratigraphy of the State is described in some detail. The bulletin is accompanied by a geological map on which the formations of the State are outlined in much greater detail than in any previous publication.

In 1893, Professor Raphael Pumpelly (162) called attention definitely to the time intervals which must have elapsed between the Vicksburg Limestone and the Chattahoochee group. He states that the evidence of a time break exists in:

1. The almost general presence of a limestone conglomerate at the base of the Chattahoochee immediately overlying Eocene fossils. This conglomerate is sometimes a breccia, and often like a rock shattered in place; but more often it consists of clearly rolled pebbles of limestone not distinguishable from the Eocene rock below.

2. The surface of demarcation between the Eocene and the Chattahoochee is very irregular. The Eocene rises island-like into the Miocene. The altitude differs considerably at this point but a few miles along the strike."

In 1903 W. H. Dall completed his extensive publication on the Tertiary fauna of Florida, the first issue of which appeared thirteen years earlier. These researches, making up volume 3, parts 1-6, of the Transactions Wagner Free Institute of Science, contain the most detailed investigation that has yet been made on the invertebrate fauna of Florida. A discussion of the geologic results is given in part 6, pages 1541 to 1620 (42).

Descriptions of the vertebrate fossils of Florida by the veteran paleontologist Joseph Leidy are contained in the Transactions of the Wagner Free Institute of Science, volume II, 1889, and volume IV, 1896, the latter edited by F. H. Lucas.

The paleogeography of Florida has been freely discussed in literature and has given rise to a diversity of views. Evidence of minor changes of level of the peninsula have been recorded by a number of observers. A mild elevation of the peninsula during Post-Pliocene time was suggested by Conrad to account for the elevated position of Post-Pliocene formations along the east, south, and west coasts (28). Tuomey (196), after examining the mainland of southwest Florida and the Florida keys, was of the opinion that it was necessary to recog-

nize an upward movement to account for the present elevation of this region.

Louis Agassiz (6) and Hunt (103), both of whom examined the keys with care, were of the opinion that no such movement had occurred.

In order to account for the character of the orange sands of Mississippi and Louisiana, Professor E. W. Hilgard (94) believes it necessary to assume that previous to its deposition the Gulf coast suffered an elevation of at least 450 feet above its present level, followed during the Champlain epoch by a slow depression of at least twice that amount, with finally a re-elevation of at least 450 feet. While these minor changes of elevation are believed by Hilgard to have affected more particularly the axis of the Mississippi Valley, they doubtless also extended to Florida.

Smith (186), in summarizing the geological history of Florida, notes that the axis of elevation which brought the Vicksburg Limestone above sea, probably lay to the west of the center of the present peninsula, the western coast then lying probably 100 miles west of its present position. To account for the Orange Sand as then understood, Smith postulates the submergence of Florida during the Champlain epoch, followed by a re-elevation to the present height.

The elevations which were believed to have affected the West India Islands during the early Quarternary led Dana (53) to assume that Florida was necessarily affected by the same movements. Dana argues further that the subsidence that brought Florida to its present level occurred during the era of formation of the Florida coral reefs. A mild subsidence of the west coast of Florida to account for the surface configuration was suggested by Heilprin (92) in 1887. Mild folds, with axis parallel to the peninsula, were observed by Dall along the Caloosahatchee River in 1887 (42).

Kost, in 1887, recognized the anticlinal axis traversing the Florida peninsula (113), while Johnson (105), in

his sketch illustrating the structure of the peninsula, likewise indicates its anticlinal structure.

The fact that the marine deposits in Florida are drained of salt originally present in the interstices of the rock for nearly a thousand feet below sea level, as indicated by bored wells, together with solution cavities at considerable depth, led Shaler (181) to postulate an elevation of the peninsula at some time since its formation to not less than 800 to 1000 feet.

McGee's memoir on the Lafayette formations (138) contains the writer's conclusions as to the history of the coastal plains during late geographical times. Previous to the formation of the Lafayette the coastal plains, in the opinion of McGee, had been for a long time quiescent. In order to account for the Lafayette formation McGee, like Hilgard, finds it necessary to postulate an extensive submergence, involving the entire coastal plains. It is, however, considered as not absolutely certain that southern Florida was submerged (p. 509). Following the Lafayette deposits an elevation occurred bringing the southern coastal plains much above their present level. Previous to the Lafayette deposits canyons were cut by rivers across the coastal plains. McGee estimates this elevation as 200 to 700 feet above the present level. A re-submergence, not so extensive as that of the Lafayette, but involving Florida, is indicated, in the view of McGee, by the presence of the Columbia sands on top of the Lafayette. A Post-Columbian high level period, followed by subsidence to the present level, closes the history of the coastal plains.

In regard to the supposed elevation of land north of the Gulf of Mexico postulated by Spencer, Upham and others to account for the glacial epoch, Dall (45) maintains that for Florida, at least, no such elevation occurred. Canyons and sculpturing of the topography such as would necessarily have occurred in the soft Florida formation, being absent.

In his preliminary sketch of the phosphates of Florida, George H. Eldridge (66) expresses the view that the entire area of Florida was re-submerged to receive the mantle of superficial sand which forms such a prominent feature of its surface.

In 1895 J. W. Spencer published a paper (193) in which he postulates the elevation of the Antillean and surrounding region sufficient to connect the two Americas by way of the West Indies. Two main periods of elevation are recognized. The first occurred in the Pliocene period. This is followed by a period of depression during the late Pliocene or possibly early Pleistocene, which corresponds, Spencer believes, to the Lafayette depression described by McGee. The land rose again to a great elevation during Pleistocene time, uniting the continents by way of the Antillean bridge. A subsidence followed in the later Pleistocene, which submerged most of Florida. This depression corresponds to the depression during which the Columbian series was formed on the continent. After this subsidence the land rose 150 to 200 feet above the present level, with subsequently slight depression to its present level. Spencer concludes that the Antillean bridge stood from one and a half to two and a half miles above the present altitudes of the plains which now form the islands:

"It has been found that there have been two epochs of great elevation, namely, in the Pliocene and in the Pleistocene periods. Between these there was a subsidence of such depth as to drown the continental coastal plains and reduce the West Indian region to very small islands, with (probably) a shallow connection between the Atlantic and Pacific oceans. The mid-Pleistocene depression was not quite so great as the earlier and there was probably a strait connecting the two oceans. Since that time there have been several oscillations of minor degree, with the formation of many small coastal canyons and the elevation of terraces and coral reefs."

To the conclusion of Spencer, Dall (42) enters a vigorous objection. He states (pp. 1544, 1545, 1546):

"Dr. J. W. Spencer has propounded some very startling

hypotheses, involving the elevation of some of the Antilles and Florida many thousand feet and their submergence within a comparatively recent period of geological time.

"The, on the whole, remarkable horizontality of the Floridian strata indicates a freedom from violent changes of level from the time the Peninsular limestone first emerged from the sea. Landshells in the Ocala limestone show that the then dry land existed. South of the Suwannee Strait, closed in late Miocene time, there is no evidence of subsequent submersion to any serious extent. Two gentle flexures run parallel with the peninsula, having the lake district between them; a tilting of, at the most, thirty feet, up at the east, down at the west, which may have been contemporaneous with the flexures; and, for the rest, very slow and slight but probably nearly continuous elevation never exceeding one hundred feet and perhaps less than half that, with dry land and fresh-water lakes constantly existing since the Ocala islands were raised above the sea; such is the geological history of the Florida peninsula. Denudation of the organic limestone by solution rather than erosion is the prominent characteristic of the changes in the surface. Soft, crumbling under the finger nail, the rocks of the plateau, if lifted five or six thousand feet, as claimed by Dr. Spencer, would have been furrowed by canyons and swept bodily into the sea. Indeed, to me the proposition is inconceivable as a fact and incompatible with every geologic and paleontologic fact of south Florida which has come to my knowledge."

In reply to Dall's chief objection, that the peninsula if elevated would have been deeply scarred and cut by canyons, Spencer maintains (194) that part of Florida which now constitutes the peninsula was during the period of elevation a remnant of a plateau not yet dissected.

BIBLIOGRAPHY OF FLORIDA GEOLOGY.

The following list of papers includes all publications relating to the geology of Florida of which record has been obtained. The list is necessarily lacking in completeness and notice of omissions will be appreciated. Those papers, the place of publication and title of which have not been verified from the original are followed by an asterisk.

1. Agassiz, Alexander—

The Tortugas and Florida Reefs.*

Am. Acad. Mem. II, 107-134, 12 pls. 1883; reviewed by J. D. Dana, Am. Jour. Sci. (3) XXVI, 408-409, 1883; Abst. Am. Nat. XVII, 1267-1268, 1883.

2. Agassiz, Alexander—

A Contribution to American Thalasography. Three cruises of the U. S. Coast and Geodetic Survey steamer *Blake* in the Gulf of Mexico, in the Caribbean Sea, and along the Atlantic Coast of the United States from 1877 to 1880. In two volumes, vol. I, XII, 314 pp. maps; vol. II, 219 pp. pls. Cambridge, 1888.*

Mus. Com. Zool. Bul. XIV and XV.

3. Agassiz, Alexander—

Note (on coral reefs of southern Florida and their relations to the growth of the peninsula).

Mus. Comp. Zool. Bull., XVI, 157-158, 1890.

A Note appended to Shaler's paper (No. 178).

4. **Agassiz, Alexander—**
Note on the Florida Reef.
Am. Jour. Sci. (3) XLIX, 154-155, 1895.

Letter to J. D. Dana, dated Tampa Bay, Florida, December 27, 1894. The Miami Limestone is regarded as of Aeolian origin. Agrees with Tuomey as to elevation of the outer reef.

5. **Agassiz, Alexander—**
The Elevated Reef of Florida.
Mus. Com. Zool. Bull. XXVIII, No. 2, 29-62, 26 pls., 1896.

6. **Agassiz, Louis—**
Florida Reefs, Keys and Coast.
U. S. Coast Survey Rept. for 1851. (Appendix No. 10), 145-160, 1852.

Extracts from the report of Professor Agassiz to the Superintendent of the Coast Survey.

7. **Agassiz, Louis—**
Relation of the Geological and Zoological Researches to General Interests, in the development of Coast Features.
U. S. Coast Survey Rept. for 1867, 183-186, 1869.

Letter addressed to the Superintendent of the Coast Survey.

8. **Agassiz, Louis—**
Report on the Florida Reefs.
Mus. Comp. Zool. Mem. VII. pp. 1-40, 1880.

Report of Professor Agassiz to the Superintendent of the Coast Survey (letter referred to in No. ~~7~~ 6 in full).

9. **Aldrich, Truman H.—**
A New Conus from the Tertiary of Florida.
Nautilus XVI, 131-132, 1903.

Describes *C. Waltonensis* from Shoal Creek, Walton County.

10. Aldrich, Truman H.—

New Species of Tertiary Fossils from Alabama, Mississippi and Florida.

Nautilus, XVI, 97-101, 1903.

11. Allen, John H.—

Some facts respecting the Geology of Tampa Bay, Florida.

Am. Jour. Sci. (2) I, 38-42, 1846.

12. Bailey, J. W.—

Discovery of an Infusorial Stratum in Florida.

Am. Jour. Sci. (2) X, 282, (1-5 p.), 1850.

This is an advance notice of the infusorial stratum described in the following.

13. Bailey, J. W.—

Microscopical Observations made in South Carolina, Georgia and Florida.

Smithson. Contri. Knowl. II, art. VIII, 48 pp. (3 pls.), 1851.

The observations on Florida occupy pages 14-25. The geological references occur on pages 16 and 19, the first relating to the limestone 40 miles west of Palatka, the second to a supposed infusorial stratum at Tampa.

14. Bailey, J. W.—

Silicified Polythalamia in Florida.

Am. Jour. Sci. (2) XI, 86, (1-4 p.), 1851.

This is an extract from the preceding with the addition of list of genera identified.

15. Bartram, William—

Travels through North and South Carolina, Georgia, east and west Florida, the Cherokee Country, the extensive territories of the Muscogulges or Creek Confederacy, and the Country of the

Choctaws, containing an account of the soil and natural productions of those regions, together with observations on the manners of the Indians. 522 pp. 6 pls. map.

Philadelphia, 1791; second edition printed in London, 1794.

16. Bland, Thomas—

Physical geography of and distribution of terrestrial mollusca in the Bahama Islands.*

New York Lyceum of Nat. Hist. Annals X, 311-324; abst. Am. Jour. Sci. (3), VIII, 231-233, 1874.

17. Boyer, Charles S.—

A fossil marine diatomaceous deposit at St. Augustine, Florida.*

Torrey Bot. Club, Bull., XXII, 171-174, 1895.

18. Bradley, Frank H.—

"Geological chart of the United States east of the Rocky Mountains and of Canada", New York, 1875.*

19. Brewer, William H.—

Warren's New Physical Geography, 144 pp., Philadelphia, 1890.*

20. Brown, Lucius, P.—

The Phosphate Deposits of the Southern States.

Eng. Assoc. South. Proc., XV, No. 2, 53-128, 1904.

Phosphates of Florida described on pp. 63-86.

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(Elevations in Florida).

Am. Jour. Sci. (2), XVII, 407, 1854.

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Sur les Variations observees dans la composition des apatites, des phosphorites, et des phosphates sedimentaries. Remarques sur le gisement et le mode de formation de ces phosphates.*
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The Natural History of Carolina, Florida and the Bahama Islands: Containing the figures of Birds, Beasts, Fishes, Serpents, Insects, and Plants: Particularly, those not hitherto described, or incorrectly figured by former Authors, with their Descriptions in English and French. To which is prefixed A New and Correct Map of the Countries; with Observations on their Natural State, Inhabitants, and Productions. By the late MARK CATESBY, F. R. S. Revised by Mr. Edwards. Linnæan Index of the Animals and Plants. Vols. I and II, London, MDCCLXXI, 1771.

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Correlation Papers: Eocene.
U. S. Geol. Sur. Bull. 83, 1891.

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26. Codington, E. W.—
The Florida Pebble-Phosphates.
Am. Inst. Min. Eng. Trans. XXV, 423-431, 1896.

27. Conrad, Timothy A.—
Observations on the Tertiary and more recent

formations of a portion of the Southern States.*
Acad. Nat. Sci. Phila. Jour. VII, 116-129, 1834.

28. Conrad, Timothy A.—
Observations on the Geology of a part of East Florida, with a Catalogue of Recent Shells of the Coast.
Am. Jour. Sci. (2) II, 36-48, 1846.

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Descriptions of new species of Organic Remains from the Upper Eocene Limestone of Tampa Bay.
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30. Conrad, Timothy A.—
Observations on the Eocene formation in the vicinity of Vicksburg, Miss.
Acad. Nat. Sci., Phila. Jour. (2), I. 111-134, (pls. XI-XIV), 1850.

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Acad. Nat. Sci., Phila. Proc. XVII, 184, 1865.

Three species of invertebrates identified from Ocala, and the formation referred to the Eocene (Shark River Marl of New Jersey).

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An Intermediate Pliocene Fauna.*
Am. Nat. XXIII, 253-254, 1889.

33. Cope, Edward D.—
(Note on the fossils of the Alachua clays) contained in U. S. Geol. Sur. Bull. 84. 130, 1892.

Alachua clays regarded as probably intermediate between the Loup Fork and the Equus beds.

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Rept. 8th International Geographic Congress held in the U. S. in 1904, 599, (1-2 p.), 1905.

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An extensive deposit of phosphate rock in Florida.*

Am. Nat. XXIV. 1185-1186, (5-6 p.), 1890.

36. Cox, E. T.—

Florida Pebble and Nodular Phosphate of Lime.*

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Wash. Biol. Soc. Proc. XVII, 1-6, 1904.

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Origin of the Coral Reefs and Islands.

Am. Jour. Sci. (3) XXX, 89-105, and 169-191, map, 1885.

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Report of the State Engineer and Geologist, contained in Message of the Governor of Florida submitted with Accompanying Documents. November 28, 1854.

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Notes on the Geology of the Florida Phosphate Deposits.

Am. Jour. Sci. (3) XLI, 102-105, 1891; abst. Eng. Min. Jour. LI, 210, (1½ cols.) 1891.

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Record of a Deep Well at Lake Worth, southern Florida.

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Preliminary List of Deep Borings in the United States. part I.

U. S. Geol. Sur. Water Supp. and Irri. Paper, No. 57, 1902.

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65. Eldridge, George H.—

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69. Finch, John—

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Studies on the Chipola Miocene of Bainbridge, Georgia, and Alum Bluff, Florida.

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The Upper Vicksburg Eocene and the Chattahoochee Miocene of Southwest Georgia and adjacent Florida.

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75. Gorrie, —. —

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Sections made in 1901 of the Chattahoochee series in northwestern Florida, contained in Comparison of the Oligocene by C. J. Maury.
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The Geology of Florida is briefly summarized on pp. 137-138. The Geological map is based, so far as Florida is concerned, on that previously issued by Smith, with the exception that the area indicated by Smith as probably Eocene is here mapped as Vicksburg.

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The classification and paleontology of the U. S. Tertiary Deposits.
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Meyer having questioned the Oligocene age of the Vicksburg, Heilprin reiterates his views.

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Science, VI, 499 (1-8 p.), 1885.

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88. Heilprin, Angelo—
(Tertiary Fossils from Kentucky, Texas and Florida).
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The Later Tertiary of the Gulf of Mexico.
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Notes on the Geology of the Island of Cuba.
Mus. Comp. Zool. XVI, No. 15, 243-288, 9 pls. 1895.

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Pop. Sci. Mon., Dec. 673-683, 1905.

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100. Horsford, E. N.—
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Am. Jour. Sci. (2) XIV, 245-253, 1852; Am. Assoc. Adv. Sci. Proc., 207-215, 1852.

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This paper is a further defense of the views presented in the preceding and is a reply to criticism by Dana.

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Science, V, 396, 1885.

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Am. Jour. Sci. (3) XXXVI, 230-236, 1888.

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Am. Jour. Sci. (3) XXXIV, 70, (1-3 p.), 1887.

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Am. Assoc. Adv. Sci. Proc., XXXV, 231, (1-2 p.) 1887.

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Geology of the Coastal Plain of Alabama.
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117. LeConte. John—
On the Optical Phenomena presented by the "Silver-Spring," in Marion County, Florida.
Am. Jour. Sci. (2), XXXI. 1-12, 1861.

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On the Agency of the Gulf-Stream in the Formation of the Peninsula of Florida.
Am. Assoc. Adv. Sci. Proc., pt. 2. 103-119, 1857.

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Science, II, 764, 1883.

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120. Ledoux, Albert R.—
The Newly-discovered Phosphate-beds of Florida.
New York Acad. Sci. Trans. IX, 84-94, 1890; Eng. Min. Jour. XLIX, 175-177, 1890; Sci. Am. Supp. XXX, 12104-12105, No. 758, 1890.

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Fossil Bones from Florida.

Acad. Nat. Sci. Phila. Proc., 309-310, 1887.

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Notice of some Fossil Human Bones.

Wag. Free Inst. Sci. Trans. II, 9-12, 1889.

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The Lafayette Formation.
U. S. Geol. Sur. 12th Ann. Rept. pt. 1, 347-521, 1891.

139. McGee, W. J.—
Discussion following paper by J. W. Spencer on, "Terrestrial Submergence southeast of the American Continent."
Geol. Soc. Am. Bull. V, 21-22, (1-2 p) 1893.

140. MaClure, William—
Observations on the Geology of the United States.
Am. Philo. Soc. Trans. VI, 411-428, map, 1809; Jour. de Phys. LXIX, 204-213; ibid. LXXII, 137-165, map, 1811.

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Observations on the Geology of the United States of North America; with remarks on the probable effects that may be produced by the decomposition of the different classes of Rocks, on the nature and fertility of soils; applied to the different States of the Union, agreeably to the accompanying geological map.
Am. Philo. Soc. Trans. I, (n.s.) 1-91, 2 pls. and map, 1818. Published in book form Philadelphia, 1817.

This is a revised and enlarged edition of the above. The rocks of Florida are referred to the Alluvium class of the Wernerian system. Northern Florida as far south as the line crossing the peninsula, just below St. Augustine, is included in the map and represented as alluvial.

142. MacGonigle, John N.—
The Everglades of Florida.
Rept. of the 8th. Inter. Geol. Cong. held in the United States in 1904, 767-771, 1905.

143. Marcou, Jules—

Geological Map of the United States and British Provinces of North America, 92 pp. 8 pls., Boston, 1853.*

Reviewed in part by W. P. Blake, Am. Jour. Sci. (2), XXII, 383-388, and by Anon, ibid XVII, 199-206.

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Uber die Geologie der Vereinigten Staatem und der englishchen Provinzen von Nord-Amerika.*

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Reviewed by J. D. Dana, Am. Jour. Sci. (2) XXVI, 323-334, 1858; XXVII, 137-140; by A. Agassiz XXVII, 134-137, 1859.

146. Maury, Carlotta J.—

A Comparison of the Oligocene of Western Europe and the Southern United States.

Am. Paleont. Bull. No. 15, 118 pp. 1902.

The Oligocene of Florida is described on pp. 45-67.

147. Memminger, C. J.—

Florida Kaolin Deposits.

Eng. Min. Jour. LVII, 436, 1894.

Describes the kaolin beds in Lake County, and includes copy of analysis of sample.

148. Merrill, George P.—
On Fulgurites.
U. S. Nat. Mus. Proc. IX, 83-91, 1887.

Describes two tubes from near Pensacola formed of sand particles fused to glass by lightening.

149. Merrill, George P.—
Stones for Building and Decoration, 453 pp. New York, 1891.*

150. Merrill, F. J. H.—
Barrier Beaches of the Atlantic Coast.*
Pop. Sci. Mon. XXXVII, 736-745, 1890.

151. Meyer, Otto—
The Genealogy and the Age of the Species in the Southern Old-Tertiary.
Am. Jour. Sci. (3) XIX, 457-468, and XXX, 60-72, 421-435, 1885; Reviewed by E. W. Hilgard, ibid, 266-269; E. A. Smith, ibid, 270-275; T. H. Aldrich, ibid., 300-308, 1885: abst: Am. Nat. XX, 511, (1-8 p.) 1886.

The reference to Florida occurs on pp. 67-68, where Heilprin's mapping of the Oligocene of Florida is criticized.

152. Meyer, Otto—
The Classification and Paleontology of the U. S. Tertiary Deposits.
Science, VI, 143-144, 1885.

Replies to Heilprin's criticisms (No. 85 and 86).

153. Millar, C. C. H.—
The Phosphate Fields of Florida. 48. pp.*
Eden, Fisher & Co., London, 1890.

154. Mitchell, Samuel L.—

Observations on the Geology of North America, illustrated by the description of various organic remains found in that part of the world.*

Cuvier's Essay on the Theory of the Earth. 319-324, 3 pls., New York, 1818.

155. Murray, John—

Report on the Specimens of Bottom Deposits. Report on results of dredgings under the supervision of Alexander Agassiz in the Gulf of Mexico, in the Caribbean, and along the Atlantic Coast of the United States by the U. S. S. *Blake*.

Mus. Comp. Zool. XII, No. 2, 37-61, 1885; abst: Am. Jour. Sci (3) XXXI, 221-225, 1886.

Records the occurrence of concretions of phosphate of lime in the Strait of Florida.

156. Neal, J. C.—

(Discovery of another bed of fossil bones in the Alachua Clays.) Communicated to Joseph Leidy.

Am. Nat. XIX, 834, (1-8 p.) 1885.

Cinders and charred bones were found two to three feet below the surface.

157. Penrose, R. A. F., Jr.—

Nature and Origin of Deposits of Phosphate of Lime, with an introduction by N. S. Shaler.

U. S. Geol. Sur. Bull. 46, 143 pp. 3 pls, 1888.

The phosphates of Florida are referred to on pp. 78-79 This bulletin contains a bibliography of publications on phosphate up to 1887.

158. Pierce, James—

Notices of the agriculture, scenery, geology, and

animal, vegetable and mineral productions of the Floridas and of the Indian tribes.
Am. Jour. Sci. IX, 119-136, 1825.

159. Porter, J. T.—
Properties and Tests of Fuller's Earth.
U. S. Geol. Sur. Bull, 315, 268-290, 1907.

160. Pratt, N. A.—
Ashley River phosphates. History of the Marls of South Carolina, and of the discovery and development of the native bone phosphates of the Charleston Basin, 42 pp. Philadelphia, 1868.*

161. Pratt, N. A.—
Florida Phosphates. The origin of the bowlder phosphates of the Withlacoochee River district.*
Eng. Min. Jour. LIII, 380, 1892.

162. Pumpelly, Raphael—
An Apparent Time-break between the Eocene and the Chattahoochee Miocene in Southwestern Georgia.
Am. Jour. Sci. (3), XLVI, 445-447, 1893.

163. Ries, Heinrich—
The Clays of the United States East of the Mississippi River.
U. S. Geol. Sur. Prof. Paper, No. 11, 298 pp. 1903.
The clays of Florida are briefly described on pp. 81-86.

164. Rogers, Henry Darwin—
Oolite in Florida.
Acad. Nat. Sci. Phila. Proc. II, 210-211, (1-8 p.) 1846.
The fossils contained in a specimen of oolite from Florida seemed to refer the formation to the latest Tertiary.

165. Sanford, Samuel—
Record of deep well-drilling for 1905.
U. S. Geol. Sur. Bull. 298, 1906.

Wells of Florida recorded on pp. 46-51.

166. Say, Thomas—
Fossil shells found in shell mass from Anastasia Island. (Contained in "Description of a Testaceous Formation at Anastasia Island" by Dietz, R.)
Acad. Nat. Sci. Phila. Jour. IV, 78-80, 1824.

167. Schoeph, Johann David—
Beitrage zur mineralogischen Kenntniss des ostlichen Theils von Nord-Amerika und seinen Gebirge. 194 pp. Erlangen, 1787.*

168. Sellards, E. H.—
Some Sink-hole Lakes of North Central Florida.
Am. Assoc. Adv. Sci. Proc. LV, 378-379, 1906; Science XXIII, 289-290, 1906.

169. Sellards, E. H.—
The Geology of Florida in Relation to its Artesian Water Supply.
Florida State Hort. Soc. Proc. 117-121, 1906.

170. Sellards, E. H.—
Occurrence and Use of Artesian and other Underground Water.
Florida Agri. Exp. Stat. Bull. 89, 91-113, 1907.

171. Sellards, E. H.—
The Origin of Sink-holes.
Science (n.s) XXVI, 417, 1907.

172. Sellards, E. H.—
Fuller's Earth, Kaolin, and Peat in Florida.
Eng. Min. Jour. LXXXV, 1187, 1908.

173. Shaler, N. S.—
Report, Atlantic Coast Division.
U. S. Geol. Sur. 9th. Ann. Rept., 71-74, 1889.

Reference to investigations made in Florida occurs on pp. 72-73.

174. Shaler, N. S.—
Report of the Work of the Atlantic Coast Division.
U. S. Geol. Sur. 10th Ann. Rept. pt. I, 117-119, 1890.

175. Shaler, N. S.—
General account of the fresh-water morasses of the United States with a description of the Dismal Swamp district of Virginia and North Carolina.
U. S. Geol. Sur. 10th Ann. Rept. pt. I, 255-339, figs. 2-38, pls. 6-19, 1890.

Contains description of Mangrove swamp.

176. Shaler, N. S.—
(Discussion following paper by J. B. Tyrrell.)
Geol. Soc. Am. Bull. I, 409, (1-2 p.) 1890.

From recent investigations believes that a depression in glacial times or about the time of the last glacial period, permitted the Gulf Stream to flow over Florida up to the northern portion of the Lake district.

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Note on the Value of Saliferous Deposits as Evidence of former Climatal Conditions.
Boston. Soc. Nat. Hist. Proc. XXIV, 580-585, 1890.

Reference to Florida occurs on p. 584. Postulates elevation of Florida at some time to a considerable height above sea to account for the drainage of salt water from the rocks to a depth of nearly a thousand feet.

178. Shaler, N. S.—

The Topography of Florida.

Mus. Comp. Zool. XVI. No. 7, 139-156, pl. 1890; abst: Am. Nat. XXIV, 768, 1890.

179. Shaler, N. S.—

Residual Ablation Deposits. (Contained in paper on "A Preliminary Sketch of the Phosphates of Florida," by Eldridge, George H.)

Am. Inst. Min. Eng. Trans. XXI, 1893.

180. Shaler, N. S.—

The Geological History of Harbors.

U. S. Geol. Sur. 13th. Ann. Rept. pt. 2, 93-209, 1893.

The harbors of the Florida Coast are described on pp. 130-134 and 180-193.

181. Shaler, N. S.—

Evidences as to Change of Sealevel.

Geol. Soc. Am. Bull. VI, 141-166, 1895.

Discusses oscillation of levels in Florida pp. 154-155. Regards cavities in the limestone at considerable depth as evidences of previous elevation.

182. Shepard, Charles Upham—

Geological Observations upon Alabama, Georgia and Florida.

Am. Jour. Sci. XXV, 162-173, 1833.

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